

Opportunity study for the implementation of gesture recognition technology in the hospital environment

Commercialization through a university spin-off

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Guinevere's ambition is to become a **spin-off** from UCLouvain specialized in interaction between surgeons and medical imaging during operations. Guinevere will offer a software that allows surgeons to **control medical imaging** in real time with a simple hand gesture. This innovation will allow surgeons to **save precious time** while ensuring a **sterile environment**.

Price: €330 /month

Management:

- Bastien Nothomb - CTO
- Tancrède d'Aspremont Lynden – CMO
- Harry Usuwiel – CFO
- Jean Wilberz - CEO

Potential partners:

LTTO, UCLouvain, Leap Motion, DICOM and PACS softwares, hospitals.

Business: Integration of a gesture sensor in medical imaging softwares.

Customers: Hospitals with at least one operating room.

Market: 104 hospitals in Belgium with at least one operating theatre.

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The opportunity

The time lost by surgeons to view and manipulate medical images during operations.

Strategy

Guinevere aims to become a UCLouvain Spin-off in order to benefit from the hospitals owned by the university. In addition, the company's solution will be offered on a monthly subscription basis.

Technical aspects

Guinevere owns a prototype of a DICOM viewer ISO12052 compliant with a modular gesture recognition engine and a Leap Motion sensor. The gesture recognition engine will be integrated in existing DICOM viewer.

Operational Plan

Guinevere will launch its activity in January 2021. After more than a year and a half of tests. The first two years will only be dedicated to the solution's implementation in the UCLouvain hospitals. Then, other hospitals will be targeted.

Funding

We have estimated our funding needs at €80 000. This financing will be organized in 2 phases:

1. The launch phase: €20 000
2. The commercialization phase: €60 000

	Financial forecasts				
	2021	2022	2023	2024	2025
Combined market shares	0%	2%	6%	7%	8%
Turnover	0	€ 110 880	€ 257 400	€ 300 960	€ 344 520
Net income (+/-)	-€ 4 108	-€ 42 088,25	€ 84 374,08	€ 95 428,57	€ 123 425,49
Break-even point	0	€ 158 514,41	€ 161 907,56	€ 165 955,46	€ 169 907,71
Return on investment	-26%	-125%	71%	54%	61%

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CHAPTER

1

INTRODUCTION

Guinevere deals with the problem of controlling medical imaging in operating rooms. Since surgeons must preserve their hands' sterility while performing surgery on a patient in order to avoid infectious risks, they cannot directly control their patients' medical data displayed on operating screens. These hygienic constraints are either forcing surgeons to scrub up their hands after each time they interacted with the keyboard and mouse allowing them to consult medical data, or to require assistance from a nurse controlling the data in their regard.

Guinevere would like to offer a touchless gesture-based solution to allow surgeons to control medical data without having to touch any surface, and therefore allowing them to keep their hands sterile. This solution would ensure patients' safety while giving surgeons control of their data without needing any assistance or having to face any constraints.

The aim of this thesis is to answer the questions raised by the creation of such a technological company. First, the objective is to confirm that this idea of implementing a gesture recognition technology in the hospital environment is a real business opportunity. Second, the aim will be to define how such a technology could be developed and how it could be implemented. The third objective will be to define if such an implementation could be profitable from a financial standpoint. The final objective will be to identify the best way of creating such a company, both from a legal and communication point of view.

To provide answers to those questions, this thesis is organized in seven chapters. Each

one is focusing on a specific Guinevere related topic. At the beginning of each chapter, the reader will find a short introduction explaining its content. Furthermore, each chapter is concluded with a summary table gathering the main information previously exposed. That way, the reader will be able to quickly know what the chapter is about and how it is concluded.

Chapter 2 aims at presenting Guinevere's team as well as its mission, vision and values, but also at introducing the context of gesture representations. Since Guinevere is about the commercialization of a touchless technology, it was important to determine how the company intends to explain its target users the necessary gestures to use the technology developed in this thesis.

Chapter 3 outlines Guinevere's strategy and targeted market. It presents seven different markets that Guinevere could have targeted. It also explains why the medical market was chosen and expands on its details with different analysis, such as the PESTEL analysis, the Gartner Hype Cycle, as well as the SWOT and TOWS analysis. The decision to create a university spin-off is also explained and a business model canvas is presented.

Chapter 4 aims at presenting Guinevere's product details, namely how it was developed and how it works. Furthermore, this chapter expands on the information given in chapter 2, by depicting the gesture representations that will be given to Guinevere's users for them to know how to use the product.

Chapter 5 presents Guinevere's communication plan, namely how the company intends to reach its users and start selling its solution.

Chapter 6 gives all the legal details surrounding Guinevere. The advantages of creating a company, the reasons why the limited liability status is the most adapted, as well as the process to submit a patent protecting Guinevere's technology are presented.

Chapter 7 presents the financial results forecasts of Guinevere for a five-year period from January 2021 to December 2025.

Chapter 8 is dedicated to risk management and introduces the different risks induced by setting up a company such as Guinevere, and how those risks can be counterbalanced.

A conclusion answering the questions presented earlier in this section will close the thesis. It will be followed by appendices where the reader will be able to find extra information that could not be presented as a direct part of the thesis' main text.

CHAPTER

2

PROJECT OUTLINE

This chapter first presents Guinevere’s team as well as the project’s mission, vision and values. Then, the focus is put on defining gestures and how to represent them for end-users. The aim of this chapter is to define how gestures can be represented efficiently so that Guinevere’s end-users know what they have to do in order to use the product correctly.

2.1 Founding Team

Guinevere’s team is made up of four students from different faculties and with different skills.

Jean Wilberz is studying Business Engineering at the Louvain School of Management and has already led multiple entrepreneurial projects successfully. For instance, under the student-entrepreneur status made available by UCLouvain, Jean was able to develop side businesses in different domains, such as customized merchandises for companies or beer tasting activities for both companies and individuals wishing to have an introduction to this beverage. Furthermore, Jean was a key member of the student entrepreneurs club “UStart” between 2016 and 2019, by endorsing different roles such as Vice-President and President of UStart LLN, or even Wallonian Representative for the club at a national scale.

Harry Usuwiel is studying Management Sciences at the Louvain School of Management

and has already been able to develop hard skills in both Finance and Accounting. Thanks to his international experience, Harry was able to develop an effective “problem-solution” approach, which allows him to have a strong analytical capacity as well as an ability to study the problems under a lot of different angles.

Bastien Nothomb is studying software engineering at the Polytechnic School of Louvain and has already been able to develop hard skills in coding, web development and cyber-security. Furthermore, Bastien has had multiple occasions to bring his skills into the business world, namely by working for a CPME-Alumnus founded startup: The VEX-Virtual Experiences. Without Bastien’s personality and skills, this thesis could never have been achieved.

Tancrède d’Aspremont Lynden is studying Information & Communication at the Communication School of Louvain and has already acquired a couple of professional experiences. By working in a Digital Media Agency called blue2purple, developing a podcast called L’Ambassade, spending two years at UStart with Jean Wilberz, and by most recently joining the Belgian scale-up called Sortlist as a Content Manager, Tancrède has been able to develop practical skills in communication as well as digital marketing.

Thanks to those different skills, Guinevere’s team has the advantage of being complementary.

2.2 Mission, Vision and Values

For an entrepreneur, being able to describe why his company exists, what it is striving to achieve, and how it is planning to reach its objectives is necessary to have landmarks guiding him along his entrepreneurial journey (Cady, Wheeler, DeWolf, & Brodke, 2011).

Because entrepreneurship is such a rough path to follow in one’s professional career, it can be very common for entrepreneurs to get so caught up in the race that they are forgetting why they started running in the first place (Cady et al., 2011). Having a clearly defined and aligned mission, vision, and values is not only necessary to bear in mind where the company is headed to. Indeed, once an entrepreneur starts creating a team, it is necessary to provide those team members a clear understanding of where the company is going, why it is going there, and how it will get there in order to maximize productivity and the chances of success (Falsey, 1989).

Furthermore, having a strong mission, a strong vision, and guiding values can also be a way to position the company on the market, allowing it to have a differentiation strategy for the creation of its brand. Indeed, companies can communicate openly on what they stand for in order to create their brand identity, but also to build their brand community.

Brands that have strong values as well as a strong vision and mission tend to attract individuals that can connect with them, which will lead them to develop a sense of commitment towards those brands (Muniz & O’guinn, 2001). Brand communities have many advantages and can be a serious asset for companies wishing to speed up their growth as well as strengthening their positioning on the market (Muniz & O’guinn, 2001). Many examples can be cited, the most well-known probably being Harley Davidson and Apple, but Nutella and Saab also have strong communities around them (Muniz & O’guinn, 2001).

For all those reasons, clear statements of a mission, a vision, and values have become common and expected in every type of organization, regardless of industry, size or profit status (Cady et al., 2011).

2.2.1 Mission

A mission statement deals with questions such as “Why are we here?”, “Why do we exist?”, “What are we doing?”, “For whom are we creating value?”. The mission of a company is the statement explaining its purpose and what it tries to achieve. Such a statement allows the company to know what value it is creating, for whom that value is created, but also to better define the actions it can undertake to achieve that mission (Grusenmeyer, 2009).

The mission of Guinevere is to develop and improve the possible interactions happening between humans and machines through gesture recognition. More precisely, Guinevere strives to create value for surgeons by allowing them to interact with medical imagery displays through touchless technology in order to avoid facing hygienic constraints and infectious risks for their patients.

2.2.2 Vision

The vision statement explains how the company would like things to be in the upcoming years. The vision statement is a picture of the future the company is striving to build by accomplishing its mission on a daily basis (Grusenmeyer, 2009).

Guinevere’s vision is a world where surgeons can interact with technology in a flawless and natural way, allowing them to perform surgery on patients without the fear of infectious risks implied by physical contacts with operating rooms devices. On a more global scale, the vision is a world where humans and machines interaction have become so natural that technology is now enhancing every aspect of people’s daily life.

2.2.3 Values

Values state what is important to the company and the people behind it (Fagiano, 1995). They drive what we believe in, what we stand for, and guide our behavior as entrepreneurs (Grusenmeyer, 2009).

As a team, we defined five core values that were aligned with Guinevere’s mission and vision, which are the following:

Practicality refers to the ease of use and pain solving Guinevere provides its target users by allowing them to interact with operating room devices through touchless technology. We should always focus on solving their pain points in the most practical way in order to facilitate their adoption of the product.

Progress refers to the will of making things go forward and making things better. Progress is also what keeps us growing as entrepreneurs and what motivates us to always learn more and help more people around us.

Safety is what makes us develop a highly effective technology that will help doctors perform surgery on patients in the safest possible way.

Health as being healthy is a sine qua non condition to thrive as human beings. Health has played a role in choosing to target hospitals and operating rooms for touchless interaction, because it allows a better protection of the patient’s health.

Boldness is a necessary value that any entrepreneur should have. Entrepreneurship is a rough path, with many challenges. To face all those challenges, boldness is necessary to reach objectives, try things, fail and learn fast, in order to succeed.

2.3 Introduction to Gestures

As Guinevere’s core business is deeply related to gestures, a clear definition of what a gesture is must be given. According to the Oxford English Dictionary, which is the principal dictionary of the English language, a gesture is "a movement of part of the body, especially a hand or the head, to express an idea or meaning"(Lexico, 2020). Gestures are a way to communicate. They can either transfer an idea on their own, such as the contact of the thumb and forefinger to capture and express the idea of precision, or they can embody a meaning and strengthen an accompanying speech (McNeill, 2006).

Gestures are a natural way for humans to communicate to their peers, but they are also becoming a way to interact with technology. According to *GestureML Wiki* (2019), gestures can be acquired in three different ways in order to interact with a piece of

technology: through surface (touch input), computer vision (motion input), and wearables (sensor input).

Surface refers to gestures that require the user to either touch a gesture recognition surface, such as a touchpad or a smartphone screen for instance, or use a pointer such as a mouse or a stylus. This kind of input implies that a contact must be happening between the user and the piece of technology in order to allow the interaction to take place.

Computer vision refers to gestures that require the user to use 3D objects, pose and motion to create an efficient gesture interaction with a piece of technology (*3D Motion Gesture Index / GestureML Wiki*, 2019). Instead of using a mouse, a stylus, or a gesture recognition surface such as a touchpad or a screen, the interaction is happening thanks to a hand and finger tracking device that can recognize 3D gestures. Among those devices, the Leap Motion, the RealSense, the Duo3D, or the PMD Pico can be cited (*3D Motion Gesture Index / GestureML Wiki*, 2019). This is only for gestures performed with the users' hands, but a wide variety of sensors exist: eye, head, or even body tracking devices are a reality as well.

Wearables refers to gestures that require the user to wear a sensor in order to interact with a piece of technology. Those sensors, also known as wearables or wearable smart devices, can track the gestures performed by the user in real time. Among those wearable devices allowing gesture interactions, the Myo Armband and the Nod Ring can be cited as examples (*Sensor Gesture Index / GestureML Wiki*, 2019). It is also possible to have hand held devices, such as the Nintendo Wii controller for instance.

In addition to their method of acquisition, gestures can also be classified according to their form. Only the shape of the 3D gestures made with the hand will be discussed here, being the type of gesture used in our product (see chapter 3 for the choice of the application case). The taxonomy used is inspired by Du, Degbelo, and Kray (2019) and the sub-categories of Aigner et al. (2012).

- Stroke: Only the overall movement of the hand determines the gesture.
- Static pose: The hand pose is held in one position without any changes.
- Dynamic pose: The hand pose changes but the hand does not move.
- Static pose with motion: The hand pose is held as the hand moves.
- Dynamic pose with motion: The hand pose changes as hand moves.

2.3.1 Touch-based and Touchless Gestures

Based on the explanations in the section 2.3, gesture recognition can be separated into two broader categories: **Touch-based gesture recognition** including *surface input* and **Touchless gesture recognition** grouping *computer vision* and *wearables input*.

Touch-based gesture recognition is a technology that is already widespread in our society as it is used daily by most people through smartphones and all other devices that can be controlled by touch interfaces.

Touchless gesture recognition presents more complexity in its usage as there is no physical resistance which therefore cannot give a confirmation by the sense of touch to the user. The latter is composed in two parts:

- **2D recognition**, which requires a simple camera to capture a gesture, is the most present on the market but does not have the best recognition rate.
- **3D recognition** allows a higher recognition rate of the gestures. Thanks to the arrival of dual cameras on the back of smartphones such as the iPhone 11, the Samsung S10 or even the Pixel 4 of Google, 3D recognition is growing (Technavio, 2015).



Figure 2.1: Touch-based Gesture (Financial Express, 2016).



Figure 2.2: Augmented Reality - apoQlar (Leap Motion, 2020).

2.4 Common Graphical Language for Gesture Representations

As presented in the previous section, humans can interact with machines in many different ways. However, this variety also implies a need to communicate how those gestures must be performed to allow users to effectively use technology. In the following pages, the problems implied by gesture representations are explored. Understanding those problems will allow a better definition of Guinevere's own gesture representations.

2.4.1 Growing Adoption of Technology

Since the 1970's, progress in computer technology has created an industry that supplies products and services used in almost every industries, institutions and households (Bernstein, McCreless, & Cote, 2007).

This fact brings up the question of technology adoption and diffusion among society. Diffusion is the process in which an innovation is communicated through certain channels over time among members of a social system, while innovation is an idea, practice or object that is perceived as new by an individual (Rogers, 2003). The diffusion of innovations can be attributed to a large set of different factors, one of them being technology improvement in its performances (Zhang & Berger, 2009). As technology improves, its diffusion in the marketplace will be impacted in a positive way (Zhang & Berger, 2009). However, improvements must be assessed according to a specific key performance indicator, related to a key component of the technology being assessed (Christensen, 1992). In the case of computers, the key component is the processor, and its key attribute is speed.

When technology improves, information about the new product being released becomes more appealing, which drives consumers to be more likely to spread the news about the concerned product, leading to a faster diffusion of the product (Zhang & Berger, 2009). Improvements are not the only factor impacting the growing adoption of technology, network externalities have a role to play as well. Network externalities happen when consumers benefit more from the consumption of a product or a service thanks to other individuals (Katz & Shapiro, 1986). In other words, the benefits an individual can get from the use of a good often depends on the number of other individuals using compatible goods (Katz & Shapiro, 1986). For instance, the more people are using WhatsApp, the more interesting it becomes to start and keep using WhatsApp because more people can be reached and contacted through that application.

The growth of technology adoption has impacted industries such as healthcare or banking (Chang, 2005; Bernstein et al., 2007). As information technology is becoming more affordable, more powerful, more reliable, more accessible and more versatile, the healthcare industry keeps developing a stronger dependency towards that technology (Bernstein et al., 2007). Whether it is for maintaining patient records, scheduling, billing and accounting, or materials management, this industry depends on information technologies because they allow a better delivery of healthcare (Bernstein et al., 2007).

The banking industry has also been largely influenced by the evolution of technology. The application of computerized network to banking allowed a reduction in the cost of transactions and increased the speed of services deliverability (Chang, 2005).

2.4.2 Introduction to Human-Computer Interaction

This growth of technological adoption came with new kinds of interactions happening between humans and technology. People living in the 1980's did not have the same ways of communicating with machines of their time as the men and women of the 2020's will have with present and future technologies because the way users are interacting with products is defined by the way those products have been designed (Chin, Diehl, & Norman, 1988). Phones and the evolution of their features as well as their design are an example as such. Back in 1980, mobile phones could hardly hold in one's pocket, and interactions with humans were limited to a dozen of buttons that could be pressed in order to dial a number.

Because phones of that time had limited capabilities, the amount of interactions humans could have with this technology was limited as well. Since the Motorola DynaTAC 800x was released in 1983, mobile phones have known a serious development of their features, allowing more interactions humans could have with them. Nowadays, an iPhone 11 Max Pro user can interact with his phone through touch, voice and face recognition to access a wide range of features. The same kind of evolution is touching technology as a whole, which is leading to more complex interactions humans can have with it.

2.4.3 Complexity in Human-Computer Interaction

With the development of the latest wearable and mobile devices, more sophisticated interaction styles are becoming available to the users (McAweeney et al., 2018). Interactions happening between humans and computers can be done in different ways thanks to a wide range of channels: keyboards, mice and tablets, voice, but also hand gestures (Rempel, Camilleri, & Lee, 2014). Most 2D gestures are making the end-users move their fingertips across the surface of touch sensing displays and touchpads, which can recognize gestures like pinching, flicking and swiping (Radhakrishnan, Lin, Zeid, & Kamarthi, 2013). With the development of technologies such as Leap Motion, interactions between humans and computers happening through 3D hand gestures are becoming possible. Those technologies will lead to an increased complexity of the gestures allowing interactions between humans and technology because 3D gestures are more complex than 2D gestures (Rempel et al., 2014).

This development of technology will increase the need from humans to communicate unfamiliar symbolic input in order to trigger the features expected from the machines they are interacting with (McAweeney et al., 2018). A relevant example of that situation would be the AirPods Pro released by Apple on October 30th, 2019. The AirPods Pro are wireless Bluetooth earbuds. Thanks to the Bluetooth technology, end-users can listen without wires to audio content coming from their phone, tablet or computer. The optical sensors included in the AirPods Pro allow them to detect in and out-ear placement, as well

as pressures on their stems. Those optical sensors are broadening the scope of potential interactions an end-user can have with his audio content player. In 1980, end-users had the Sony Walkman, which had a set of buttons to turn it on and off, to go forward, and to go backward. The AirPods Pro serve the same purpose as the Sony Walkman, which is listen to music, but interactions with the technology have changed. The optical sensors allow those earbuds to automatically detect in and out ear placement, which means that users do not have to turn them on and off anymore: they do it on their own.

Furthermore, the stems, where different kinds of strains can be performed, allow multiple features: a long strain will activate / deactivate noise cancelling; a short strain will pause / play the audio content; two rapid strains will make the audio go forward and skip to another piece of audio content; three rapid strains will make the audio go backward in order to come back to the beginning of the audio content being listened to.

This example shows that the way users are interacting with products is largely defined by the way those products have been designed (Chin et al., 1988). There is also a link between the development of technology and the level of complexity that characterizes the interactions happening between humans and current gesture-based systems (Rempel et al., 2014). This situation brings up a question: How can gesture representations be designed to help users form the correct mental models to make the leap from symbolic communication to actual gesture enactment in order to trigger the expected features coming from the technology (McAweeney et al., 2018)?

2.4.4 The Absence of a Common Graphical Language

Knowing how to represent and communicate gestures to end-users is of great importance in order to reach four objectives: understanding, memorizing, guiding, and marketing.

A good gesture representation must allow users to understand quickly and memorize easily which kind of gesture they must perform in order to use a piece of technology. Furthermore, gesture representations can also be used as a marketing asset in order to communicate effectively the different features a user will be able to access thanks to a company's product. While the first two objectives are discussed in the following pages, the marketing aspects of gesture representations are presented in chapter 5, in the section 5.4 more precisely, which is dedicated to Guinevere's key messages.

As technology improves, more features are becoming available through gestures. Technology manufacturers have to figure out how they can use graphics and illustrations to design the gestures that will trigger the features available on their new piece of technology. Another problem is the uncertainty that end-users will interpret and enact the depicted gestures correctly (McAweeney et al., 2018).

Even though the amount of gesture-based systems is increasing, there are very few broadly accepted conventions to articulate the elements of a gesture in a common graphical “language” (McAweeney et al., 2018). This keeps the gesture-based systems industry busy with problems such as defining the best way to use graphics and illustrations to create representations of gestures that will be understood and enacted correctly by end-users.

This problem remains unsolved because no widely accepted graphical language for gesture representations exists yet, despite the advantages it would create.

Indeed, for end-users, it would help them in having a quicker learning, a faster task performing, a reduced error rate, and a faster recall (McAweeney et al., 2018). If every gesture-based system released by different companies were using the same graphical language, users would not have to learn how to use each new system they buy. That would lead to faster adoption. This is especially true for technologies allowing 3D hand-gestures recognition since they offer the potential for an improved user experience, thanks to a bolstered productivity and ease of learning (Rempel et al., 2014).

User experience, as mentioned by Rempel et al. (2014), will indeed have a role to play in the commercialization of Guinevere’s product and the assessment of the results it can provide.

2.4.5 What is User Experience

As of today, there is no clear definition of what User Experience (UX) is exactly (Kieffer, Rukonic, Kervyn de Meerendré, & Vanderdonckt, 2019). According to the International Organization for Standardization (ISO), UX refers to a "person’s perceptions and responses that result from the use or anticipated use of a product, system or service" (Kieffer et al., 2019). However, this definition is not widely accepted, and UX researchers think that clarifications could be brought to it. Today, it seems that two schools of thoughts exist regarding UX research. Bargas-Avila and Hornbæk (2011) explain that some researchers tend to focus on the hedonic aspect of UX, which refers to the pleasure a user can feel when using a product, while others give more importance to the pragmatic characteristics of an interactive product, like usability, utility and safety.

Those two different approaches can be linked to the reasons why users decide to use an interactive product. Indeed, users can either be in a task-oriented mindset where they want to reach instrumental goals, or they can be in a non-task oriented mindset, which refers to non-instrumental goals (Kieffer et al., 2019). Hassenzahl (2018) refers to this as goal mode and action mode. In goal mode, fulfilling the goal is the main objective and it determines all of the users’ actions. In this situation, using the product is a mean to an end. In action mode, it’s the actions that motivate the users. Using the product is an end

in itself. For instance, using Microsoft Teams could be referred to as task-oriented/goal mode, while playing a video game could be referred to as non-task oriented/action mode.

Where things might get complicated is when those two approaches get mixed up. According to Hassenzahl (2018), literature on experiential marketing explains that a product should no longer just be seen as simply delivering features, it should also be providing experiences through non-utilitarian concepts such as fun, joy, or pleasure. Precisely because UX is such a wide subject, a coherent understanding of what it really is has yet to be clearly defined. Besides, according to Hassenzahl (2018), the models that do take into account pleasure as part of User Experience are both rare and too simplistic. Therefore, Hassenzahl (2018) proposes the following model to better define the key elements of UX:

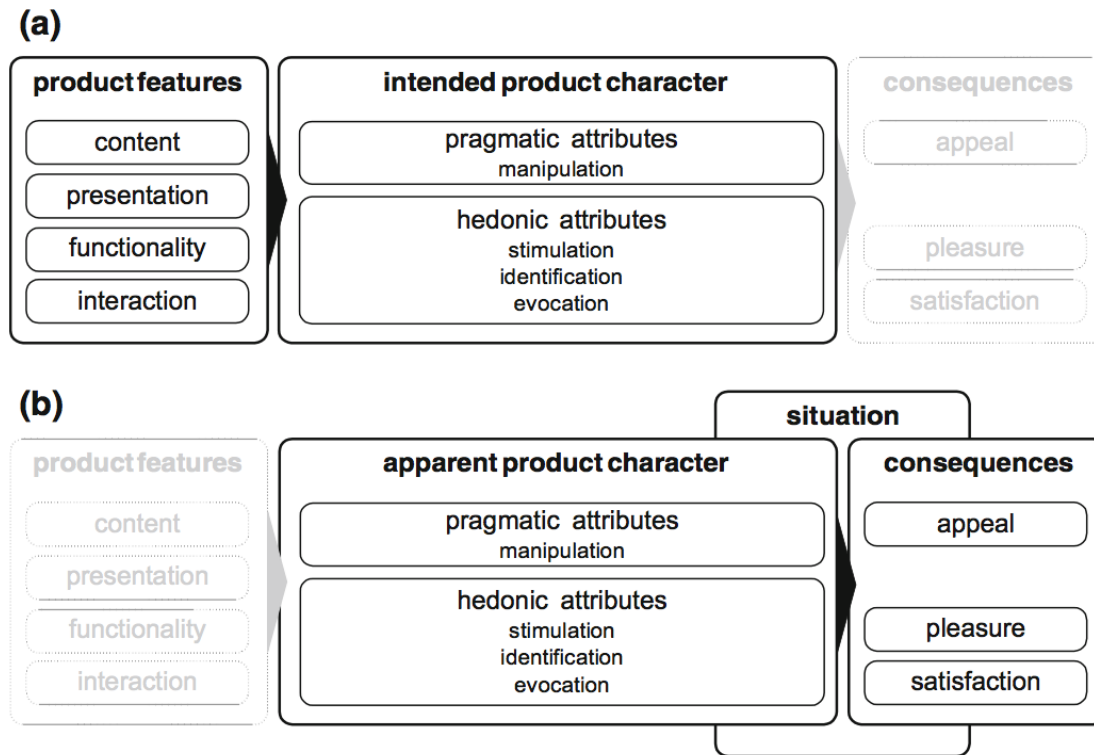


Fig. 1 Key elements of the model of user experience from **a** a designer perspective and **b** a user perspective (for details refer to text)

Figure 2.3: Hassenzahl's Model of UX Key Elements (Hassenzahl, 2018)

On this model, the product is put in the middle. This product is defined by the features that were chosen and combined by a designer. The latter has total freedom on how to combine the content, the presentation, the functionality and the interaction style to create an intended product. This product has both pragmatic and hedonic attributes. Those attributes will be perceived by the user, which will lead to consequences such as appeal, pleasure and satisfaction when encountering and using the product.

The pragmatic attributes, i.e. manipulation, offer relevant functionalities (is it useful?) to the user, and easy ways to access those functionalities (is it usable?). A pragmatic oriented product is mainly instrumental, which refers to the task-oriented mindset mentioned earlier, meaning users have a clear goal to reach. For instance, if a traveler wants to book a plane ticket, can he or she do it?

Hedonic attributes are different. When pragmatic attributes are focused on the fulfilment of individuals' behavioral goals, hedonic attributes contribute to individuals' psychological well-being and pleasure (Hassenzahl, 2018). While products will usually combine both kinds of attributes, they are rarely balanced and designers can either give more importance to pragmatic or hedonic attributes. Those two kinds of attributes can either be weak or strong, which creates four different types of products. Hassenzahl (2018) presents it this way:

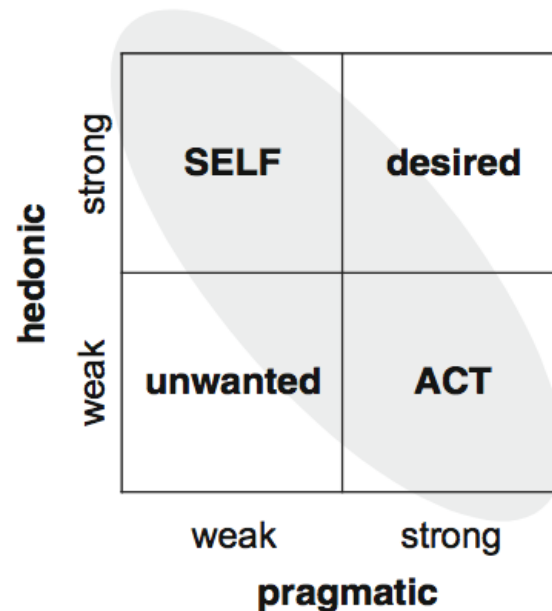


Figure 2.4: Hassenzahl's Four Kinds of Products (Hassenzahl, 2018)

For Guinevere, the aim is to create an ACT product, which is a kind of product deeply linked to the users' goals as it puts more importance on the pragmatic attributes. In the case of Guinevere, the fact of providing a relevant functionality (i.e. controlling medical data through gestures) has more weight than providing surgeons with a hedonic experience of the product. While the question of functionality is clear, the question of usability still has to be tackled. Indeed, Hassenzahl (2018) refers to pragmatic attributes as providing users with a relevant functionality (i.e., utility) and ways to access this functionality (i.e., usability). But what is usability?

2.4.6 What is Usability

According to the International Organization for Standardization (ISO), and more precisely the Standard 9241-11, usability can be described in terms of effectiveness, efficiency, and satisfaction (Bevan, Carter, & Harker, 2015). More precisely, the ISO Standard 9241-11 defines usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.” (Jokela, Iivari, Matero, & Karukka, 2003).

Each of those elements can be described as follows:

Effectiveness refers to the effectiveness with which a user can achieve a goal that was previously defined. More precisely, were users able to complete their goal and were they able to do so with accuracy?

Efficiency refers to the amount of resources that are necessary to expend in order to achieve a specific goal. More precisely, how much efforts and how much time do users need to reach their goal while using the product?

Satisfaction is defined as "freedom from discomfort, and positive attitude towards the use of the product" (Bevan et al., 2015). Therefore, after reaching their goal by using the product, are users satisfied with the product's performances?

For instance, if an individual wants to book an apartment on Airbnb, can he or she do it (effectiveness), can he or she do it easily i.e. finding the different apartments, seeing pictures, read client reviews, proceed to payment, etc.(efficiency), and is he or she satisfied of Airbnb's product when the apartment is finally booked? Following the definition of those terms, it is widely accepted that usability comes from an interaction rather than a property of a product (Bevan et al., 2015). This means that Guinevere's product must allow surgeons to control medical data (effectiveness) without efforts (efficiency) and provide clear instructions to help surgeons reach their goal (satisfaction).

2.4.7 Representing Gestures to Reach Usability

The question of how a common graphical language for gesture representations could be created still remains. It is very far from our pretension as students to create such a graphical language for gesture-based systems. However, since this thesis is about the commercialization of a gesture-based technology on a specific market, it is still necessary to know how to represent the gestures Guinevere's end-users will have to enact in order to use the technology exposed in this graduation paper. Indeed, we know Guinevere's product has to focus on pragmatic attributes and must be able to provide its users a good usability, but how can we represent gestures to reach that goal?

2.5 How to Represent Gestures

2.5.1 An Iterative Process

Taking the end-users' perspective into account is necessary to create a common graphical language for gesture representations. The creation of that graphical language can be compared to the launch of a new company. Since 2011, a way that allows to create a company with less risk has become popular. That way is called “the lean startup” and it favors experimentation over elaborate planning, customer feedback over intuition, and iterative design over upfront design (Blank, 2013). Thanks to a “get out of the building” approach, which can also be called customer development, entrepreneurs go out and ask their potential users for feedback on every elements of their business, whether it is product features, pricing, or distribution channels (Blank, 2013). Such a strategy is called agile development, which consists in building a product together with the customers and allows to eliminate wasted time by developing the product iteratively (Blank, 2013).

2.5.2 Human-Centred Design

Considering the users' opinion raises the chance of developing a product that answers their needs. The same strategy should be adopted for the development of a common graphical language representing gestures efficiently. In this case, such a strategy is called human-centred design (HCD), which consists in incorporating the users' perspective into the development process (Maguire, 2001). HCD has different key principles, but two of them are of particular interest:

- The active involvement of users and clear understanding of users as well as tasks requirements. HCD offers the advantage of involving the end-users in the design process, which leads to a better designed product, but also to a better customer satisfaction since they can feel the system was created with them rather than imposed to them (Maguire, 2001).
- The iteration of design solutions because it implies end-users' feedbacks after they used the designed solution. Those feedbacks are then used to improve the design and make it more efficient (Maguire, 2001).

HCD has therefore a role to play in the creation of a common graphical language, since it implies an involvement of the end-users as well as a consideration of their feedbacks. According to the ISO 13407 standard on human-centred design, five processes should be undertaken (ISO, 1999; Maguire, 2001): Plan the human-centred design process; Understand and specify the context of use; Specify the user and organizational requirements; Produce design and prototypes; Carry out user-based assessments.

Those steps must be conducted in an iterative process and should be repeated until the usability objectives have been reached (Maguire, 2001).

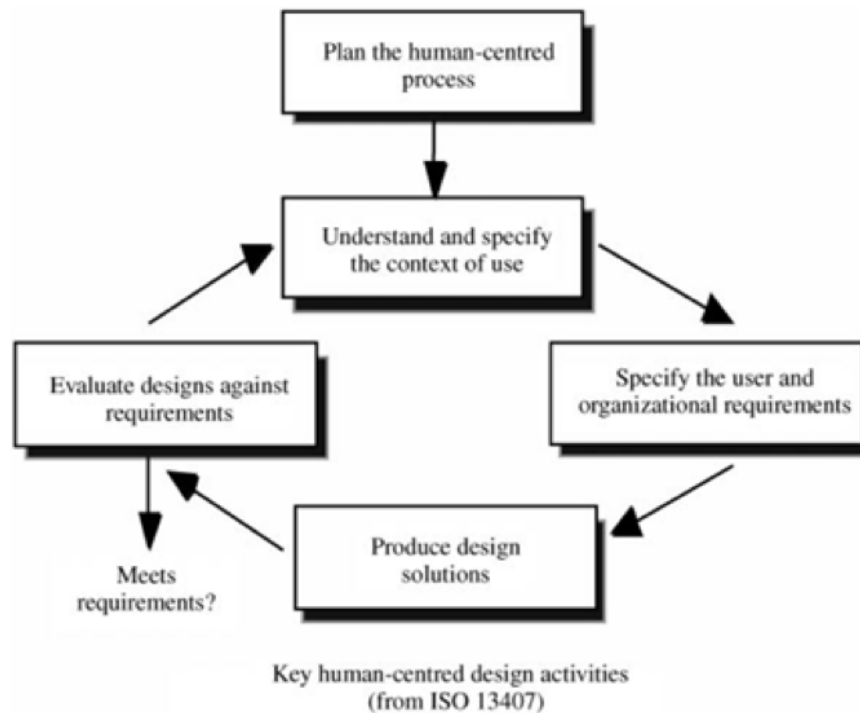


Figure 2.5: Key human centred design activities (Maguire, 2001).

As Maguire explains it, there is a process that involves end-users in the creation of products in order to reach the most efficient design, according to users' feedbacks. In an article published in 2001, Maguire develops each step that have to be followed in order to conduct an HCD properly:

Methods for human-centred design

Planning (Section 3)	Context of use (Section 4)	Requirements (Section 5)	Design (Section 6)	Evaluation (Section 7)
3.1. Usability planning and scoping 3.2. Usability cost-benefit analysis	4.1. Identify stakeholders 4.2. Context of use analysis 4.3. Survey of existing users 4.4. Field study/user observation 4.5. Diary keeping 4.6. Task analysis	5.1. Stakeholder analysis 5.2. User cost-benefit analysis 5.3. User requirements interview 5.4. Focus groups 5.5. Scenarios of use 5.6. Personas 5.7. Existing system/competitor analysis 5.8. Task/function mapping 5.9. Allocation of function 5.10. User, usability and organizational requirements	6.1. Brainstorming 6.2. Parallel design 6.3. Design guidelines and standards 6.4. Storyboarding 6.5. Affinity diagram 6.6. Card sorting 6.7. Paper prototyping 6.8. Software prototyping 6.9. Wizard-of-Oz prototyping 6.10. Organizational prototyping	7.1. Participatory evaluation 7.2. Assisted evaluation 7.3. Heuristic or expert evaluation 7.4. Controlled user testing 7.5. Satisfaction questionnaires 7.6. Assessing cognitive workload 7.7. Critical incidents 7.8. Post-experience interviews

Figure 2.6: Method for human centred design (Maguire, 2001)

Such a process is necessary because understanding how users interpret and enact gestures based on representations would facilitate the creation of a more seamless dialogue between users and gesture-based systems (McAweeney et al., 2018). Better understanding the users through HCD is important to know how to represent the gestures they will have to enact, but it is also important for choosing the gestures they will have to do. For instance, much can be learned from sign language interpreters. Because some gestures performed throughout the day can involve a real physical effort, the selection process of gestures should also consider the discomfort and pain associated with them (Rempel et al., 2014). Understanding which gestures are or are not painful will also be important in order to choose the right gestures.

2.5.3 Analysis of the Different Ways to Represent Gestures

To cope with the increasing complexity of interactions happening between humans and machines, researchers have incorporated users into the design process of gesture representations (McAweeney et al., 2018). This methodology is called Gesture Elicitation Studies (GES) and it informs the design of intuitive gesture commands on the basis of users' preferences (Villarreal Narvaez, Vanderdonckt, Vatavu, & Wobbrock, 2020). This method was introduced by Wobbrock, Aung, Rothrock, and Myers (2005), and it was designed as a way to collect end-users' preferences for symbolic input. As gestures are getting more complex, because of technology developments, it is necessary to know how to communicate and explain them to users. That is the reason why GES are being conducted since they consist in a methodology that elicits design input from users and finds consensus sets of gestures among users' proposed designs (McAweeney et al., 2018).

In other words, GES are a way to work together with end-users to better understand their preferences in order to know how to design gesture representations. GES have become a popular tool to design gesture commands, and in the last ten years, an impressive amount of design knowledge regarding user's preferences has been published (Villarreal Narvaez et al., 2020).

2.5.4 Analyzing Gesture Elicitation Studies

In an article published in 2020, called *A Systematic Review of Gesture Elicitation Studies: What Can We Learn from 5,458 End-Users ?*, Villarreal Narvaez et al. (2020) reveal they were able to identify 216 elicitation studies. The problem is that while the scientific community has been accumulating design knowledge, no serious work of systematization has been done (Villarreal Narvaez et al., 2020). According to the authors, it is time to systemize this knowledge to help the community in being more efficient to identify and apply best practices into real user interfaces as well as gesture representations.

Therefore, a wide range of data regarding end-users' preferences for gestures have been accumulated, but there is yet meaning to be made out of it. If the results of those 216 gesture elicitation studies were to be compared, and if similarities were to be found, the creation of a single graphical language could be based on those similarities.

If the results of those studies were compared, interesting insights for the design of the gestures necessary to interact with Guinevere's product may be found.

To compare those results, a taxonomy is needed to classify them according to different criteria. Many criteria can be used to classify gestures: the form, the nature, and the flow of the gesture (Wobbrock, Morris, & Wilson, 2009), the physical characteristics as well as the context of the gesture (Ruiz, Li, & Lank, 2011), the gesture type and the body parts involved (Obaid, Kistler, Kasparavičiūtė, Yantaç, & Fjeld, 2016).

In an article published in 2018, Du et al. (2018) present a table gathering different criteria that can be used to categorize gestures, based on Ruiz et al. (2011) and Obaid et al. (2016) work:

Field	Value	Description
Form	static	A static body posture is held after a registration phase
	dynamic	The gesture contains the movement of one or more body parts during the stroke phase
Nature	deictic	The gesture is indicating a position or direction
	iconic	The gesture visually depicts an icon and directly represents a real-world property
	metaphoric	The gesture visually depicts an icon and describes a real-world property in an abstract way
	abstract	Gesture mapping is arbitrary
Body parts	symbolic	The gesture is an artificial symbol that does not represent a real-world property but represents a meaning that needs to be learned and is often culture specific
	right hand only	The gesture is performed with the right hand only
	left hand only	The gesture is performed with the left hand only
	two hands	The gesture is performed with two hands
Temporal	discrete	Action occurs after completion of gesture
	continuous	Action occurs during gesture
Complexity	simple	Gesture consists of a single gesture
	compound	Gesture can be decomposed into simple gestures

Figure 2.7: Taxonomy for user-defined hand gestures (Du et al., 2018)

Using a taxonomy would lead to the detection of similarities or differences in end-users' preferences. In the context of this thesis, using such a taxonomy will help us in better defining the graphical elements we will use for our own gesture representations. To perform this analysis of the 216 Gesture Elicitation Studies identified by Villarreal Narvaez et al. (2020), two taxonomies were chosen. The first is the one of McAweeney et al. (2018), which is focused on analysing gesture representations, and the second is the one of Bernsen and Dybkjær (2010), which can be used to analyse any modality allowing to transfer information.

2.5.5 Using McAweeney et al's Taxonomy

To carry out this analysis, the framework presented by McAweeney, Zhang and Nebeling in their paper *User-Driven Design Principles for Gesture Representations* can be used (McAweeney et al., 2018).

This taxonomy gathers design elements used to communicate gestures, which are classified into 6 dimensions and 26 categories:

Dimension	Category	Dimension	Category
Perspective	1 st Person	Color	Yes
	3 rd Person		No
	Mirror	Gesture Elements	1-Sided Arrow
	Bird's eye		2-Sided Arrow
	Side Angle		Dotted Lines
Frame	Single		Ghost
	Multi		Finger Trail
Body Context	Full-Body		Other Motion Lines
	Lower-Body		Touchpoints
	Upper-Body		Numbers
	Other Body Parts		Text
Environmental Context	Physical Objects		Bending Joints
	Virtual Objects		Axis

Figure 2.8: McAweeney et al's Taxonomy (McAweeney et al., 2018).

Those elements can be combined in many ways to create gesture representations. In their paper, McAweeney et al. (2018) explain this taxonomy with further details:

- **The Perspective dimension** is related to the point of view from which the representation is built. It can be represented with a first-person point of view, with a third person point of view, from a side angle, a bird's eye or a mirror point of view.
- **The Frame dimension**, whether single or multi, explains how many frames were used to communicate different aspects of the gesture, such as space, time and motion.
- **The Body Context dimension** explains which body parts are included in the gesture representation.
- **The Environmental Context dimension** explains if objects are included in the gesture representation.
- **The Color dimension** explains if color is being used to express some particular aspects of the gesture enactment.
- **The Gesture Elements dimension** regroups all the different elements that can be added to a representation to communicate the gesture more effectively.

In their study, the authors give four examples where they use this taxonomy in order to analyze different gesture representations. However, it is important to keep in mind that this taxonomy is currently the only one allowing to analyse gesture representations

and their graphical elements, which presents upsides but also downsides. One of the upside is the speed of analysis this taxonomy provides. Thanks to a delimited number of potential graphical elements, a gesture representation can easily be read and understood. However, precisely because this taxonomy is currently the only one dedicated to gesture representations, the analysis can be limited and some dimensions might be ignored. For instance, we could imagine adding a new dimension to the taxonomy in order to analyse more aspects of gesture representations.

A potential dimension to be added could be the form of the gesture: is it dynamic or static? Is it a combination of two gestures, a dynamic one and a static one, as presented in figure D.9? Is the gesture dynamic and static at the same time as presented in figure D.4? Does it have motion in it as figure D.11 shows it or is it just a stroke like depicted in figure D.1? So this dimension of static or dynamic gesture could be added to the taxonomy in order to push the analysis of gesture representations' graphical elements.

Furthermore, McAweeney et al. (2018) taxonomy doesn't really allow to make a clear distinction between 2D and 3D gestures, or even between touch, motion, or sensor input as presented by *GestureML Wiki* (2019).

To come back on the examples presented in McAweeney et al. (2018) article, they are the following:

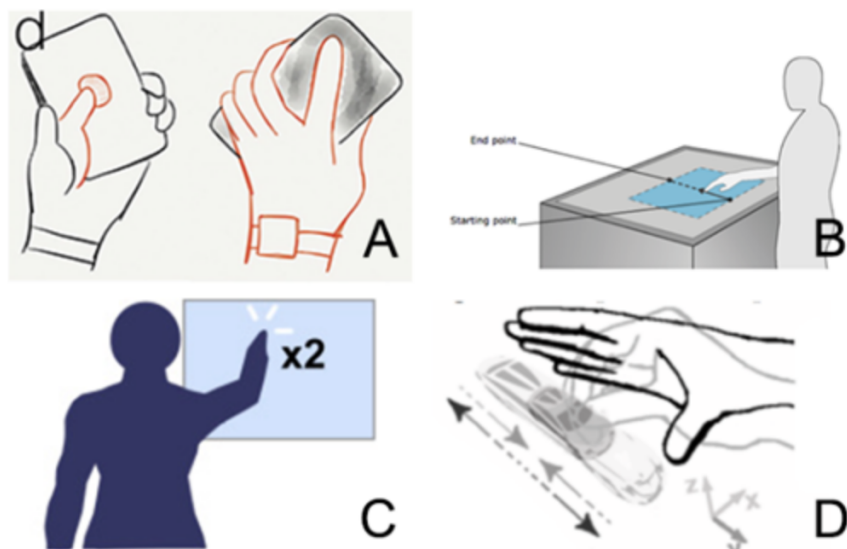


Figure 2.9: Examples of Gesture Representations (McAweeney et al., 2018).

- **In figure A**, the perspective is in 1st person, and multi-frame as well as color are used. The gesture elements “ghost” and “touchpoints” are also present.
- **In figure B**, it is a 3rd person perspective, a single frame, an upper-body context

as well as a physical object context. The gesture elements “1-Sided Arrow”, “Dotted Lines”, and “Finger Trail” are used.

- **In Figure C**, it is also a 3rd person perspective, a single frame, an upper-body context and a physical object context. Regarding the gesture elements, it is “Other Motions Lines” and “Numbers”.
- **In figure D**, it is a side angle perspective and a virtual object context as well as four different gesture elements: “2-Sided Arrows”, “Dotted Lines”, “Ghost”, and “Axis”.

Applying that taxonomy on the 216 Gesture Elicitation Studies mentioned earlier should help in discovering which design elements are the most common. Conducting that analysis would therefore reveal which elements should be used for Guinevere’s gesture representations destined to surgeons in operating rooms. That analysis was conducted, on the 216 Gesture Elicitation Studies and on an additional 45 studies for a total of 261 papers analyzed. More precisely, regarding the 45 additional studies, a new inspection of digital libraries was conducted in order to get them. That inspection was made thanks to specific queries, containing "gesture" and "elicitation" or "guessability" as well as the keyword "study". That inspection was stopped on May 1st, 2020, where as for the previous 216 studies, the inspection was stopped on August 15th, 2019.

The results can be found in figure 2.10. Most of gesture representations are made with either a first-person perspective (32%) or a third person perspective (23%) (graph a). The majority (65%) of gesture representations are using a single frame (graph b). Most gesture representations were made with hands depictions (57%). Indeed, most studies only included hands as body parts into their gesture representations and were not including the overall body context (graph c). Most studies were including physical objects (69%) in their gesture representations in order to explain with which system the end-user was interacting (a smartphone, a smartwatch or a screen for instance) (graph d). Color was an important graphical element in order to communicate the gesture efficiently. Indeed, 65% of the Gesture Elicitation Studies were including colored elements in their gesture representations (graph e). Some gesture elements are more common than others. For instance, 1-Sided Arrow (17%), Text (14%), Finger Trail (16%), Touch Points (11%), Ghost (8%), and 2-Sided Arrow (9%) were the six most commonly used elements in gesture representations (graph f).

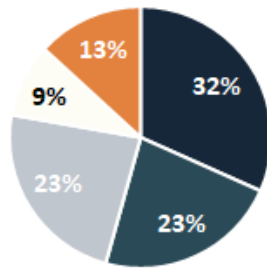
Thanks to that analysis, we know which graphical elements we should use:

- A first person or third person perspective;
- A single frame;

- Hands depiction as body context;
- The use of physical objects in order to contextualize the representation;
- Use color to emphasis certain elements of the representation;
- 1 / 2 - Sided Arrows, text, finger trails, touchpoints and ghost gesture elements.

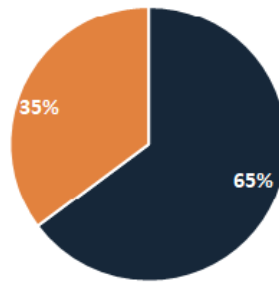
However, it is important to consider that this analysis is only based on the frequency of the graphical elements' appearances across the 261 papers that were analyzed. Originally, the idea was to confront those findings with the opinion of real professionals, to validate the fact that those graphical elements should be used for Guinevere's gesture representations. However, considering the Covid-19 pandemic that surged in Europe and the lockdown that was imposed as soon as March 2020, the interviews we wanted to conduct found themselves highly compromised. Indeed, the entire medical corps was solicited to provide answers against the crisis, and not only doctors were completely out of reach, we felt it would have been inappropriate to request their help for this thesis as they had their hands taken with sick and infected patients.

■ 1st Person ■ 3rd Person ■ Mirror
 ■ Bird's eye ■ Side angle



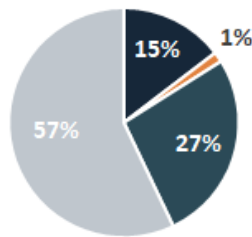
(a) Percentage of occurrences of perspective

■ Single ■ Multi



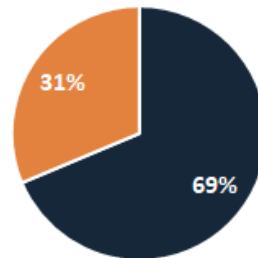
(b) Percentage of occurrences of frame

■ Full-Body ■ Lower-Body
 ■ Upper-body ■ Other part body



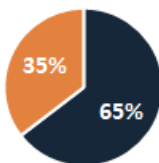
(c) Percentage of occurrences of body context

■ Physical Objects ■ Virtual Objects

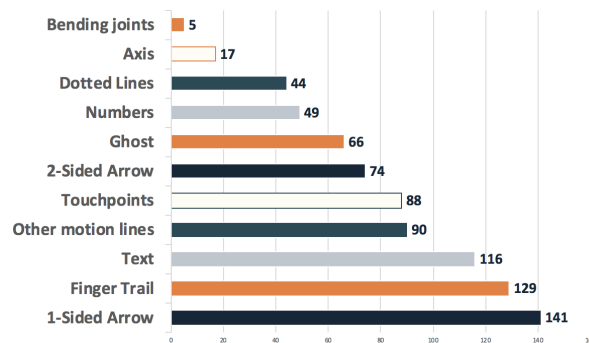


(d) Percentage of occurrences of environmental context

■ Yes ■ no



(e) Percentage of occurrences of color



(f) Number of occurrences of gesture elements

Figure 2.10: McAweeney et al's taxonomy results

2.5.6 Using Bernsen's Taxonomy

In order to push the analysis further, a second taxonomy can be used: the one presented by Bernsen and Dybkjær (2010) in their book *Multimodal Usability*.

Table 4.2 One view of the taxonomy of modalities

Super level	Generic level	Atomic level	Sub-atomic level
Linguistic modalities →	1. Sta. an. graphic ele. 2. Sta.-dyn. an. acoustic ele. 3. Sta.-dyn. an. haptic ele. 4. Dyn. an. graphic → 5. Sta. non-an. graphic → 6. Sta.-dyn. non-an. acoustic → 7. Sta.-dyn. non-an. haptic → 8. Dyn. non-an. graphic →	4a. Sta.-dyn. gest. disc. 4b. Sta.-dyn. gest. lab. 4c. Sta.-dyn. gest. not. 5a. Written text → 5b. Written lab. → 5c. Written not. → 6a. Spoken disc. 6b. Spoken lab. 6c. Spoken not. 7a. Haptic text 7b. Haptic lab. 7c. Haptic not. 8a. Dyn. written text 8b. Dyn. written lab. 8c. Dyn. written not. 8d. Sta.-dyn. spoken disc. 8e. Sta.-dyn. spoken lab. 8 f. Sta.-dyn. spoken not. 9a. Images 9b. Maps 9c. Compos. diagrams 9d. Graphs 9e. Conceptual diagrams	5a1. Typed text 5a2. Hand-writ text 5b1. Typed lab. 5b2. Hand-writ lab. 5c1. Typed not. 5c2. Hand-writ not. <i>Legend</i> <i>an.</i> = analogue <i>compos.</i> = compositional <i>disc.</i> = discourse <i>dyn.</i> = dynamic <i>ele.</i> = elements <i>gest.</i> = gesture <i>lab.</i> = labels /keywords <i>non-an.</i> = non-analogue <i>not.</i> = notation <i>sta.</i> = static <i>writ.</i> = written
Analogue modalities →	9. Static graphic →		

4.2 Which Modalities Exist? Taxonomy of Unimodal Modalities

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Figure 2.11: Bernsen's taxonomy(Bernsen & Dybkjær, 2010).

Table 4.2 (Continued)

Super level	Generic level	Atomic level	Sub-atomic level
	10. Sta.-dyn. acoustic →	10a. Images 10b. Maps 10c. Compos. diagrams 10d. Graphs 10e. Conceptual diagrams	
	11. Sta.-dyn. haptic →	11a. Images → 11b. Maps 11c. Compos. diagrams 11d. Graphs 11e. Conceptual diagrams	11a1. Gesture 11a2. Body action
	12. Dyn. graphic →	12a. Images → 12b. Maps 12c. Compos. diagrams 12d. Graphs 12e. Conceptual diagrams	12a1. Facial expression 12a2. Gesture 12a3. Body action
Arbitrary modalities →	13. Sta. graphic 14. Sta.-dyn. acoustic 15. Sta.-dyn. haptic 16. Dyn. graphic		
Explicit structure modalities →	17. Sta. graphic 18. Sta.-dyn. acoustic 19. Sta.-dyn. haptic 20. Dyn. graphic		

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4 Modalities and Devices

Figure 2.12: Bernsen's taxonomy
(Bernsen & Dybkjær, 2010).

This taxonomy regroups the different modalities that can be used to represent information, in different mediums such as graphics, acoustics and haptics inputs. Graphics means everything visual, acoustics means everything heard, and haptics means everything related to touch. Those three mediums can be used in different ways to represent multiple kinds of information. For instance, the graphics medium (everything visible) is often used to represent text, images, facial expressions, and gesture. Interacting with a system means that an exchange of information is happening, which can be done in different ways. Even though it is common to think about information in abstract terms, physics have a role to play. In some way, information is always physically transmitted, whether it is through soundwaves or light (Bernsen & Dybkjær, 2010).

Bernsen and Dybkjær (2010) call these “physical carriers of information”. Furthermore, to physically capture the information being transmitted, sensor systems are necessary, and when the information conveyed by a certain carrier gets picked up by the corresponding sense, the entity doing the perceiving gets the information and can act properly.

In their book, Bernsen and Dybkjær (2010) present a table showing the different mediums, with the physical carriers and physical sensors related to them.

Table 4.1 Medium–carrier–sense correspondences for the traditional “five human senses”

Medium	Physical carrier	Sensor system
Graphics	Light	Vision
Acoustics	Sound	Hearing
Haptics	Mechanical impact	Touch
Olfaction	Chemical impact	Smell
Gustation	Chemical impact	Taste

Figure 2.13: Bernsen’s taxonomy: mediums and carriers (Bernsen & Dybkjær, 2010).

Each of those mediums can be used through a wide range of different modalities, a modality being a way to represent information. The taxonomy presented earlier introduces all the different modalities that can be used to interact with a system, and applying that taxonomy to the 261 Gesture Elicitation Studies would also help in knowing which elements should be used for the design of Guinevere’s gestures. The table is made of four different levels : the super level, the generic level, the atomic level, and the sub-atomic level.

At the super level, there are four categories of modalities :

- **Linguistic modalities**, which are ways to represent information through language.
- **Analogue modalities**, which are ways to represent information by using similarities between representation and what is being represented.

- **Arbitrary modalities**, which is using something that does not have any specific meaning but is given meaning for a specific purpose.
- **Explicit structure modalities**, which is inserted to mark a representational structure.

From the super level, an inheritance has an impact on all three of the following levels. Each of them are created on the basis of their predecessor. For example, the analogue modalities from the super level are split into graphic, acoustic and haptic modalities at the generic level. This means that each modality is inheriting the properties of its predecessors but also has its own properties.

Just like McAweeney's, using this taxonomy will help in recognizing which modalities are the most often used in Gesture Elicitation Studies. That will allow to better understand users' preferences and therefore help in knowing what are the best ways to represent Guinevere's gestures.

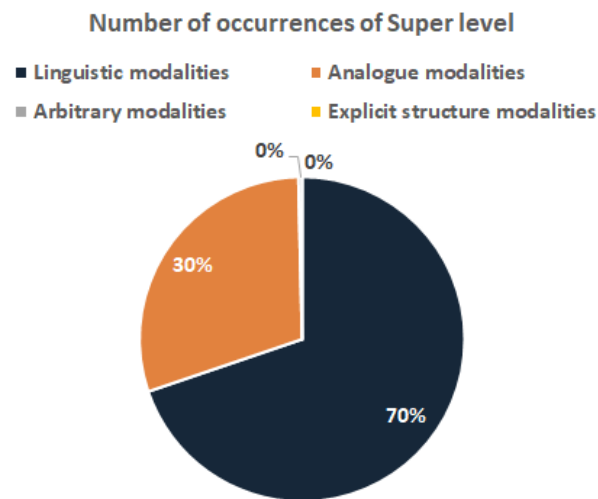


Figure 2.14: Bernsen's taxonomy: percentage of occurrences of super level

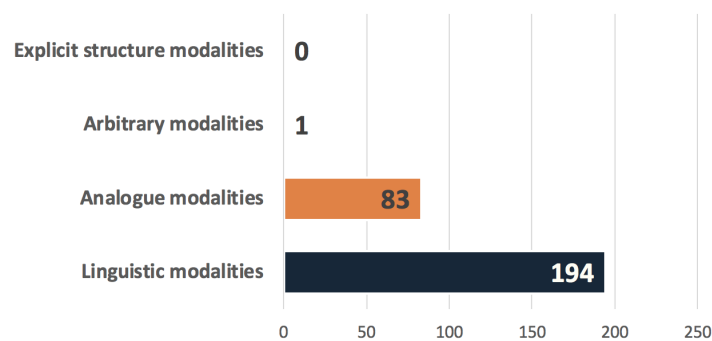


Figure 2.15: Bernsen's taxonomy: number of occurrences of super level

Linguistic modalities are largely dominant (70%) in gesture representations, followed by

analogue modalities (30%). This makes sense as language can be used through written text in order to explain the gesture that must be enacted, while analogue modalities are based on the resemblance existing between the representation and the gesture being represented.

Furthermore, three modalities of the atomic level were dominant : images (35%), written lab. (35%) and written text (28%) are the most common ways to represent gestures according to our analysis. Those ways of representing information are descending from the super levels of the analogue and linguistic modalities, which makes sense: images look like the gestures the user needs to enact while written information can give him more precise guidelines. Precisely because this thesis is focused on gesture interactions happening between humans and machines, it was important to be aware of the challenges surrounding those interactions, from a communication point of view.

Thanks to the two taxonomies presented earlier, and the analysis that were carried, we know which elements will have to be used for Guinevere's gestures representations in order to allow surgeons to use our product more easily.

If we were to interpret the data of the 261 papers that were analysed, it seems that the graphical elements that are occurring the most are the ones that simplify reality as much as possible. Arrows, colors, text, hands depiction and so forth are elements we are all familiar with. According to us, it seems that for a gesture representation to be effective, it must take a complex reality and simplify it as much as possible to provide clear instructions to end-users. The representation has to focus on the essential information the user should be aware of and it must be understood quickly. It is with this state of mind that Guinevere's gesture representations were designed. Those representations are presented in chapter 4.5.2 of this thesis, which dives into Guinevere's product, after the analysis of Guinevere's chosen market in chapter 3.

2.6 Conclusion

This chapter mainly aimed at understanding how Guinevere could leverage gesture representations to offer a good user experience to surgeons by helping them to understand how to use Guinevere's product at its best.

The learnings this chapter brought us will mainly be used in chapter 4, which presents Guinevere's solution. Indeed, the gesture representations elements that were put forward thanks to the analysis of the 261 Gesture Elicitation Studies will be used in practice. The reader will be able to find Guinevere's gesture representations in chapter 4 and in the appendix D. Furthermore, the findings about gesture representations will also be used in chapter 5, where Guinevere's marketing and communication plan is explained as well as how those representations can be used as a marketing asset.

Gesture Representations	
Context	A growing adoption of technology leading to more complex interactions between humans and machines.
Challenge	Understand the end-users and integrate them in the gesture representation designing process.
Problem	Analyse Gesture Elicitation Studies to detect what are the most common graphic elements used in gestures representations.
Taxonomies	McAweeney et al. (2018)'s one and Bernsen and Dybkjær (2010)'s one.
Results	Different elements were identified and will be used in Guinevere's gestures representations: 1) A first or third person perspective; 2) A single frame; 3) Hands depiction; 4) Physical objects; 5) Colors; 6) 1 and 2 sided arrows, text, finger trails, touchpoints, and ghost gesture elements.

CHAPTER

3

STRATEGIC ANALYSIS

This chapter aims to define Guinevere's strategy and target market. After a short introduction to the gesture market through Gartner's hype cycle, it then identifies and further analyses seven different markets that Guinevere could have targeted and explains why the medical market was chosen. It then provides more in-depth analyses, such as the PESTEL analysis, Porter's five forces, SWOT analysis, TOWS analysis, the implication of a University Spin-off and the Business Model Canvas.

3.1 Gesture Interaction Market

In this section, the global gesture interaction market will be analyzed. This world market is expected to weight \$34.25 billion in 2022, growing at a CAGR of 24,2% (Markets and Markets, 2017a). Technavio and Mordor Intelligence report similar numbers (Technavio, 2015; Mordor Intelligence, 2019). As it had been defined in the subsection 2.3.1, this global gesture interaction market can be divided into two major technologies which are touch-based gesture recognition and touchless gesture recognition.

The touch-based gesture recognition is a technology that is often linked to the finger tip tracking recognition and is mostly used with tactile interfaces such as smartphones or the track pad of a computer. As the middle class in Asian countries like China and India continues to rise, it should further contribute to a steady growth of the market (Kumar & Thomas, 2006).

The touchless gesture recognition is more complex to develop and users present difficulties in its usage. The market is smaller than the touch-based market. Despite the constraints regarding touchless gesture recognition, big manufacturers such as Intel are endowing their products with this new technology. Microsoft, Apple and Sony also invest massively in this market (Mordor Intelligence, 2019).

This growth is due to technological improvements as well as the adoption of these technologies by consumers on a daily basis: *“this technology is user-friendly and equipped with easy learning curve for the end users, which is likely to be the driver for the growth of the gesture recognition market in the forecast period”* (Markets and Markets, 2017a).

Today, touch-based gesture recognition technology has been widely embraced on the market, but the same cannot be said about touchless. The latter seems to be willing to cross the chasm of Moore (2006) which depicts the technology adoption life cycle in the global consumer market. The release of the Galaxy Note 10, that contains touchless technology, could be an example of this (Samsung, 2020).

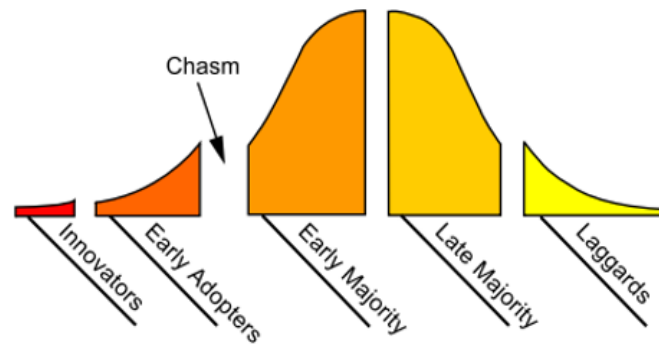


Figure 3.1: Technology adoption life cycle (Gaines, 1991).

A successful shift from an early to a mainstream market would considerably increase the market size. According to Mordor Intelligence (2019), CAGR is expected to be 27.9% for the period 2020-2025.

3.1.1 Gesture Market through Gartner Hype Cycle

Also known for its Magic Quadrant, Gartner regularly publishes forecasts of market trends that are recognized throughout the business community. On top of that, Gartner is ranked among the most admired companies according to Fortune magazine (Fortune, 2019). The Gartner Hype Cycle reports for Emerging Technologies¹, and it can be applied to the market of Global Gesture Interaction. Every year, a report is released presenting the latest

¹<https://www.gartner.com/en/documents/1752214>

<https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019/>

technological trends. Those follow a specific curve showing the public expectations. The beginning of the curve presents the emergence of a new technology. As it can be seen, in the first two phases, expectations increase rapidly but disillusionment is around the corner. The later plateau shows the integration and global acceptance of the technologies in the market. To get a clearer idea of the importance of gesture recognition, the reports published between 2011 and 2019 of the Gartner Hype Cycle has been gathered, which represent a total of 9 graphs summarized in a unique one, using the specific keywords related to gesture interaction. It shows favorable insights to the future adoption of this technology studied in this thesis. To put the results in evidence, it was decided to regroup the 7 most relevant keywords regarding Guinevere, on a 9-years graph. Close to every dot, a year is inscribed referring to the Hype Cycle publishing date. The dots represent the keywords which are: Image Recognition, Gesture Recognition, Gesture Control, Gesture Control Devices, Wearable Interface, 3D Sensing Camera and IoT. The regular presence of these keywords on the Hype Cycle represent enthusiastic previsions of these markets by the Gartner Group (Gartner, 2019).

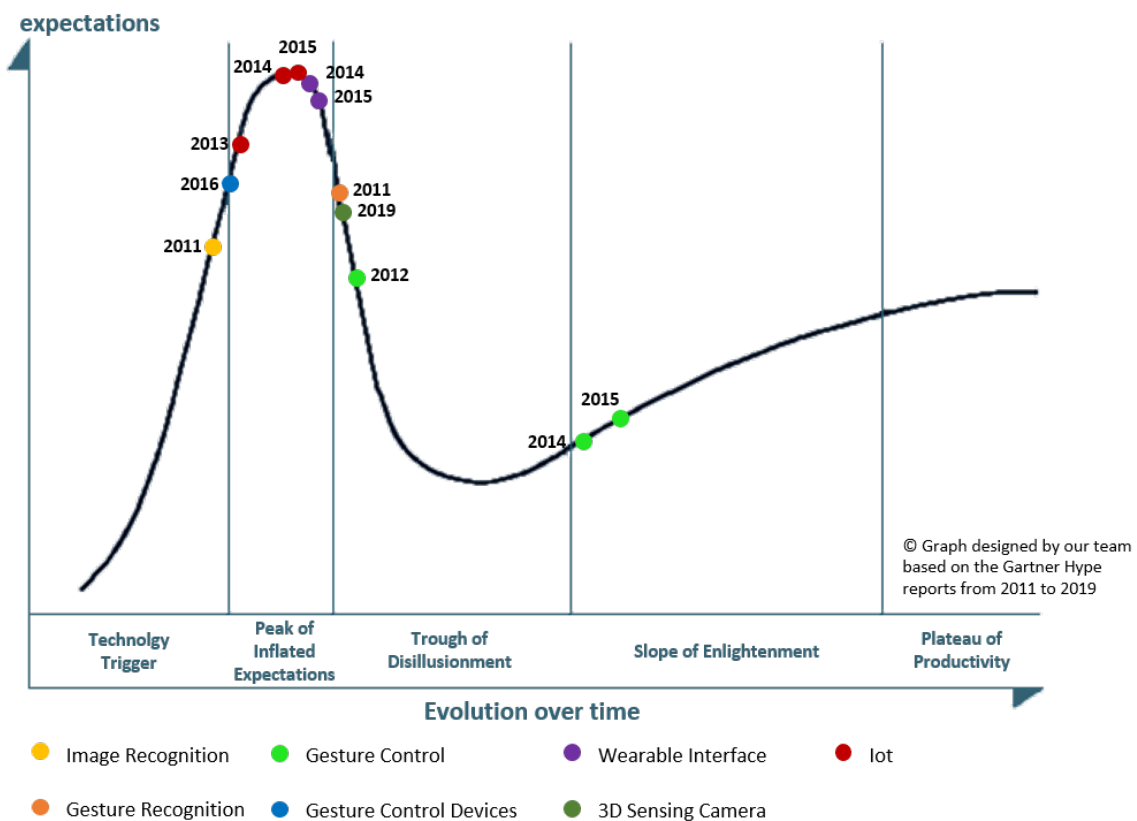


Figure 3.2: Gesture Recognition elements represented on the Gartner Hype Cycle for emerging technologies between 2011 and 2019

It can be seen that through the time, these keywords have known an evolution. In 2011, gesture recognition was progressively entering the public disillusionment phase which will be confirmed in the section 3.2.1. Indeed, the Kinect was one of the last sensor

using gesture recognition massively commercialized by a multinational which can represent this public expectations drop as it was indeed a failure on the gaming market. The term Gesture Recognition seemed to have evolved by 2012 to Gesture Control. This can be explained by the fact that gesture recognition was regularly used for machine control purposes, so the two go hand in hand. Expectations will however slowly and steadily improve in 2014 as it enters the slope of enlightenment. Again, in the next section 3.2.1 it will be progressively seen that it can be used in many more interesting applications than the one of the gaming. This short analysis of the keyword evolution shows that technologies can pivot in their market orientation, and in this case, it can be supposed that today, the plateau of productivity has been reached in the domain of gesture control.

On the basis of the overall information provided in this section regarding the gestures market, it may be concluded that the adoption of this technology is well implemented in the market. It should also be noted that the technologies are evolving, as for instance the touchless that followed the touch-based gesture recognition. The Gartner Hype Cycle is an interesting manner to stay informed about the evolution that these technologies pursue.

3.2 Potential Markets and Opportunities

In this second section of the strategic analysis, the potential markets of touchless gesture recognition that Guinevere could address are reviewed. In order to determine the market that seemed most appropriate for the gesture recognition technology developed by Professor Vanderdonckt and his team, this section was based on the readiness of the market for 2020. This readiness is based on the relationship between market demand and market supply.

More concretely, we decided to depict market demand as a relationship between market size and customer usefulness. The market size will be based on online data and the usefulness will be evaluated according to readings and opinions. The purpose is for the gesture recognition technology to solve a problem or provide a more practical alternative to a solution already existing on the market.

As far as market supply is concerned, this corresponds to the available technological advances which are able to meet market demand. Available at a specific point in time, as the learning curve for a specific technology changes over time. To place the technology on the learning curve, the BRETAM model will be used because it illustrates the evolution of the technology at the different phases it is going through (Gaines, 1991).

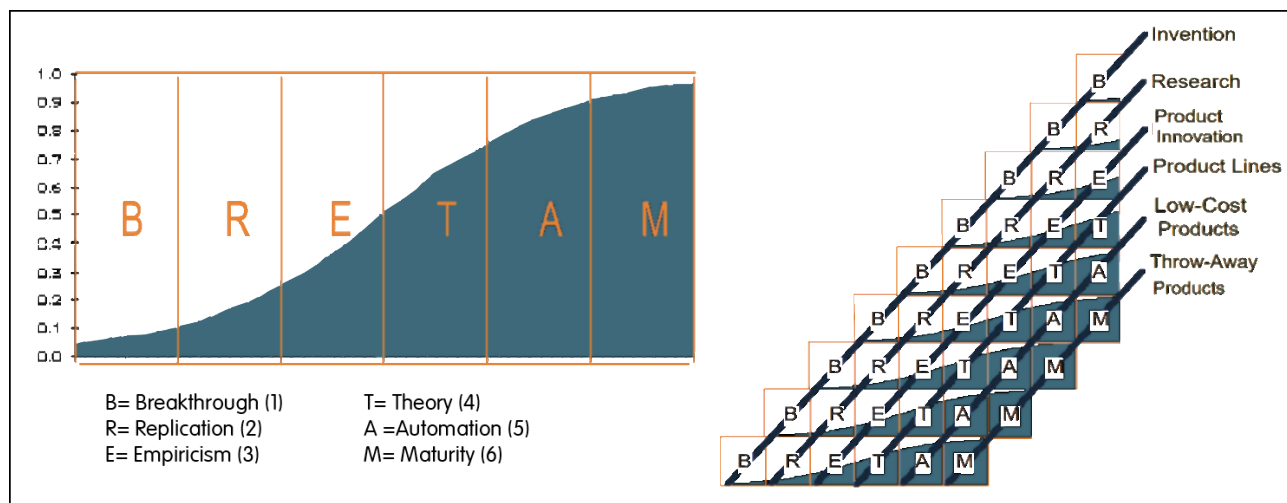


Figure 3.3: BRETAM model (Gaines, 1991).

Finally, a conclusion of the section will review the pros and cons of the most promising markets in relation to their market readiness scores (that will be calculated on a scale from 1 to 6) in the table 3.2.4, as well as the decision of the market analyzed in this master thesis.

3.2.1 Consumer Electronics Industry

Over the last decade, electronics such as smartphones have become a major part of consumers' daily lives. A study conducted by Persistence Market Research shows that the global electronics market is set to grow steadily in the coming years and should have a turnover of more than \$2 976.1 trillion in 2020 with a CAGR of nearly 15% over the period 2016-2020 (Persistence Market Research, 2016).

In the following pages, the different sub-markets in which Guinevere could be active are reviewed, namely: Gaming Consoles, Smartphones, Laptops & Tablets, Smart TVs, and Head-Mounted Displays (HMD).

Gaming Console

The size of this market was of \$39.948 billion in 2017 and it is expected to reach a size of \$49.305 billion by 2023 (Markets and Research, 2018). In addition, the market will experience a CAGR of 4.11% between 2017 and 2023 (Markets and Research, 2018). Furthermore, in 2018, global sales in this market reached 46.1 million units, the highest level since 2010 (Markets and Research, 2018). Moreover, nearly 45% of North American families and 20% of Western European families own at least one gaming console. Finally, the three main players on this market are Sony, Nintendo and Microsoft (Business Wire, 2018).

The gaming industry has shown an early interest for gesture recognition and the presence of multinational companies like Nintendo, Sony and Microsoft, has stimulated innovation in the gesture recognition sector (Ren, Yuan, Meng, & Zhang, 2013). While the Wii of Nintendo needed a controller for playing games, Microsoft had succeeded to launch a console that did not required any controller, the Kinect. It combined depth sensors, skeletal tracking, and voice recognition technologies which allowed to propel the player into an immersive way into the game, with the use of his body to play. The article **"All the money in the world couldn't make Kinect happen"** depicts the exciting story of the development of the Kinect and how it revolutionized the gaming industry. It gives an idea of all the technological innovations successfully gathered in a single product. Patrick Hackett, a game play programmer, exclaimed upon discovering the Kinect: *"Oh my God, these depth cameras are things that I never understood before and suddenly they're going to be everywhere!"*. The success was also met by the consumers as in march 2011, the Kinect was officially sold more than 10 million times and was crowned with the world record of the product with the best commercial start of the moment (Hester, 2020). Its affordable price enabled its expansion from B2B to B2C markets.

Taking advantage of the success of its cutting-edge sensor, Microsoft launched the Kinect Accelerator in 2011 that incubated startups to exploit the potential of the Kinect and to start spreading the opportunities to other markets. Thanks to this accelerator, startups have developed in many fields using the Kinect, such as education, health or for military purposes (Byford, 2012). The research and development of new application cases has also spread to the world of scientific research, which counts an aggregated number of more than 2700 results about the Kinect in the literature review (and more especially in the IEEE Xplore) by March 2019 (Guzsvinecz, Szűcs, & Sik-Lányi, 2019).

Despite that the Kinect had a high success in the gaming industry at first, in 2017, Microsoft announced that it stopped the commercializing of it as very few producers developed games on it. On the other side, new technologies with gesture recognition emerged like Virtual Reality. *"VR delivers on the promises of motion gaming in ways Kinect never could. With Kinect you were still limited to a screen, a TV screen, which was this small window into a world, while the beauty of VR is you're in the world"* (Hester, 2020).

As a synthesis of the Kinect gaming market, it can be observed that the market size had reached important figures and that users were seeing a genuine usefulness with the disappearing of the console controller. For this part, the market offer had reached maturity in the BRETAM model following the logic of García-Herranz, Haya, Alaman, and Martín (2007) which explains that when technological theories permit automation of the creation process, it leads to the possibility of manufacturing low-cost products that will become

throw-away products on the next phase. Therefore, this represents a score of 6 on the technological learning curve, which is the highest level.

However, the gaming market saw another revolution replacing technologies such as the Wii and the Kinect. The VR offered a higher immersion in the game for players as stated in the article of (Hester, 2020). This technology could be seen as a substitution of the Kinect for the gaming market. According to Gaines (1991), which makes a reference to the BRETAM model, "*Substitution occurs when an old technology has reached maturity and a new, more effective technology, reaches a point on its learning curve where it economically replaces the old one*". In other words, this means that a new BRETAM cycle starts when the substitution process has happened. The Head-Mounted Displays came as the next step of gesture recognition devices into the gaming market.

The market of HMD was estimated at \$3.25 trillion in 2016 and is expected to reach \$25.01 trillion by 2025, a CAGR of 38.8% between 2016 and 2025. Markets and Markets explains this increase is due to a growing demand for light-weight HMDs, a market adoption of VR, and investments that are made by key market players (Markets and Markets, 2017b). In addition, in 2018, nearly 28.4 million helmets were shipped worldwide. Studies show that this figure could increase by 2022 as it is expected that nearly 80.18 million helmets will be shipped worldwide (Statista Research Department, 2020).

Again, multinationals like Nintendo, Sony and Microsoft have developed those headsets technologies within their products range. While this time, Microsoft decided not to develop one for the gaming market, at least not yet. The Redmond company launched a headset for developers, the HoloLens. New important actors joined the VR gaming market such as Facebook with its Oculus takeover, Samsung with the Gear VR or Google and its Daydream headset. Even Apple plans to enter the market with its own headset (Bloomberg, 2019). This shows the high potential that multinationals see in the VR industry and that they do not want to miss this opportunity.

In terms of market demand, the high concentration of massive competitors generated a high market size thanks to their investments and the usefulness of increasing the immersive side brings an added value for game players, it gets a score attribution of 5. Concerning the market offer, at this stage of the technological learning curve of the BRETAM model, the HDM lays in the theory phase, which is represented as a score of 4 in the BRETAM model.

Smartphones

In 2019, the smartphone market weighted \$715 billion and is expected to reach nearly \$1 352 billion in 2025 with a CAGR of 11.2% over the 2020-2025 period. Moreover, approximately 358.3 million smartphones were shipped in the third quarter of 2019, a 0.8%

year to year growth, reversing seven consecutive quarters of decline (Mordor Intelligence, 2020).

While the accessible market size is much bigger than for the gaming market, the usefulness happens to be debatable. Today, gestures such as scrolling, pinching or zooming have become natural for most individuals when using their smartphone. Using touchless technology would require changing the habits of the consumers that are having a daily usage of their smartphone. The current extra applications that consumers could do with such technology do not justify the added price for a smartphone in our opinion. A parallel can be done with the 2013 decision of Microsoft to sell a package including the Xbox One and the Kinect, making the console \$100 more expensive. As a result, many game players criticized the decision of the Redmond company, so much that Microsoft decided to come back on its decision (Hester, 2020). As the smartphones are sold as a single piece, it could not be decided to choose it as an option. It seems clear that not all the consumers will desire it which reduces the potential market demand. Therefore, the market demand received an attributed score of 3.

In terms of market offer, Apple is already using face recognition on its latest iPhone models and Google has launched a smartphone that integrates touchless gesture interaction. Thanks to Soli, a chip created by Google that can be plugged into smartphones, and possibly smartwatches, it is possible to recognize different human movements at different scales such as waving and finger tapping. This chip is currently used with the new Google Pixel 4 smartphone (Google Soli, n.d.). As those technologies are new, the market for smartphone in touchless gesture recognition is located on the empiricism phase which represents a score of 3 on the technological learning curve.

Office Suites Market on Laptops

To give an idea of the potential market size, there are 200 million active users of Microsoft 365, 3.6 million users who rated Adobe Acrobat, 5 million companies using G Suite, and the 1.2 million users who rated Google Docs in the Google Play Store (Google Play, 2020; Microsoft, 2020; App Store, 2020). Therefore, the potential market could be estimated at around 250 million users. Nevertheless, this estimate is to be taken with a pinch of salt, as the exact figures of the number of users for each suite is not disclosed for Google's and Adobe's suites.

Like smartphones, laptops have become an integral part of people's daily lives. On the contrary of tactile screens, computers have peripheral devices such as the mouse or the touchpad, and the keyboard. Those allow to have a faster interaction with the machine than touchless gesture interaction according to Wipfli, Dubois-Ferriere, Budry, Hoffmeyer, and Lovis (2016a). To illustrate the type of usage that could be done with a computer,

the example of office suites will be taken where gesture recognition would replace mouse or keyboard input. Repetitive input with gestural interaction can lead to muscular fatigue known as "gorilla arm" (Hincapié-Ramos, Guo, Moghadasian, & Irani, 2014). Gesture actions should therefore be limited to only certain limited commands and coupled with the traditional use of mouse and keyboard.

In this case, the contribution of gestures for the bureaucratic suites market represents a lower usefulness for the consumer. The importance of the market size compensates the usefulness which gives it a score of 3. Concerning the market offer, laptops present the same challenges as the smartphone market which leads to an equal score.

Smart TVs

The smart TV market has a CAGR of 16.52% for the period 2020-2025. In addition, according to Grand View Research, the size of the smart TV market is expected to reach \$292.55 trillion by 2025 (Grand View Research, 2017b). Finally, according to Statista, the number of Smart TVs shipped in 2019 was 265.3 million. In terms of trends, today's TVs are increasingly equipped with 4K resolution, coupled with a growing preference for OLEDs and QLEDs (Statista Research Department, 2016).

This market offers new possibilities to its users. Indeed, smart TVs offer advanced computing capabilities and connectivity. They allow their customers to chat, search, share, browse, use programs such as Netflix or YouTube and also allow updates and downloads. Gesture recognition afford the possibility to substitute the TV controller by gestures. This can prove its usefulness as the Kinect was able to remove the controller compared to the Wii that was depending of it. Actors such as LG, Samsung, Sony, Panasonic and VIZIO are leading the market with the investments they have done in those technologies for their customers (Mordor Intelligence, 2018).

Regarding market demand, the latter has an important market size as well and presents a clear added-value and usefulness. Those two elements give a score of 4 for the market demand. On the market offer side, the phase of product innovation has already been passed which set the smart TV on the theory phase which represent a score of 4 as well.

3.2.2 Healthcare Industry

In a recent report, Deloitte highlights that *"there is a growing and aging population, rising prevalence of chronic diseases, infrastructure investments, technological advancement, evolving care models, higher labor costs amid worker shortages, and the expansion of healthcare systems in developing markets"* (Ramani, Blythe, Aparna, & Anya, 2019). In terms of economic numbers, Deloitte predicts that overall healthcare spending for the 2019-2023 period is expected to increase at a compound annual growth rate of 5%, compared to

2.7% for the 2014-2018 period. Spending is expected to increase in all regions, except for North America. The largest increases are expected in the Middle East/Africa and Asia. It is also interesting to look at the percentage of global spending on healthcare in relation to gross domestic product. This allows to measure the importance of this sector but also to compare it with other potential markets. In Belgium, this figure is expected to remain at about 10.2% until 2023, which is the current percentage (Ramani et al., 2019).

Regarding the gesture recognition market, mass electronics has the largest market share. Nevertheless, the healthcare industry is expected to have the largest increase between 2016 and 2022. The growing importance of hygiene has a considerable influence on the growth of touchless technology adoption (Markets and Research, 2019). This fast growth will allow the entry of new competitors on the market.

In the two submarkets presented here, the gaming market had an influence on it because of the Kinect. Developers changed the principal use of the device to apply it to other applications cases.

Lab, Intensive Care Units & Operating Rooms

Everything that is done in an operating room must be bacteria-free. With the help of touchless technology, a doctor might be able to control a computer by making a hand gesture while performing surgery without implying infectious risks for the patient.

Regarding market size, Statista estimated the number of operating rooms at about 405 000 in 2010 (Grand View Research, 2017a). According to the Grand View Research report, the size of the global market for operating room equipment was estimated at \$26.24 billion in 2016 and is expected to grow at a CAGR of 7.2% over the 2018-2025 period. The same report informs that growing surgical volumes, technological innovations in medical devices and an aging population are major drivers of this growth (Grand View Research, 2017a). In addition, the World Health Organization has estimated the number of surgical operations at 234.2 million each year (Weiser et al., 2008). Hospitals have a 75% market share of the global operating room market.

Since technology has played a serious role in medical progress, market readiness for a gesture recognition solution seems to be there. Remote operations and robotic operations can be taken as examples of how much the medical field is counting on the latest technology to improve patients' care. An example as such is the Da Vinci robot, which allows surgeons to operate patients remotely. It has three to four arms, one with an endoscope and the others with scalpels. The doctor controls the arms remotely using a console on which he sees the area to be operated on in 3D. By 2021, research indicates that in the United States, one out of three operations should be performed using a robot (Lentschner, 2018).

In terms of usefulness, this technology could reduce the risks of infection implied by medical imagery control but could also save surgeons time during operations. As operating rooms need important investments, this has to be taken into account in the description of the market size. From this information, the market demand is assessed as a score of 5. On the side of the market offer, many researches have been led and are continuing to be developed which place it on the BRETAM phase of the Empiricism, which is a score of 3 on the scale of the learning curve.

Sign Language

Nearly 5% of the population is considered to have hearing problems, and according to the World Health Organization, if no action is undertaken by 2030, nearly 630 million people will suffer from disabling hearing loss. By 2050, this number could be more than 900 million (World Health Organization, 2018).

However, not all of these people will have to learn sign language. For example, there are an estimated of 300 000 deaf people in the French population, a third of whom are fluent in sign language. In Belgium, the FFSB estimated an average of 11 000 people using sign language (FFSB, 2017). Those latter are inactive due to restricted access to employment and recreation (FNSF, 2015). Guinevere's software could allow the translation of sign language at any time in the daily life of hearing-impaired people. This would allow them to improve their living conditions and increase their chances of being employed.

About the usefulness of this innovation, it would allow a part of the population too often forgotten to have a greater autonomy. However, the market size is quite low as this issue affect only a small part of the population. From a social point of view, this project is very interesting, but from an economic standpoint, the market is less attractive. That is why the market demand has a score of 2.

Concerning the market offer, researches have been done in gesture recognition to apply it to sign language. Microsoft for instance dedicated a team of researchers to make some progress with the Kinect (Wu, 2013). However, sign language is subject to nuances, particularly in terms of facial expressions, which are difficult to perceive with today's technologies (World Health Organization, 2018). Moreover, there are 137 different sign languages in the world which makes it difficult to provide a solution for all those languages (World Health Organization, 2018). This is why in the case of this market, it will be justified that its offer has a lower score than other more mature markets presented before. The attributed score for this market is mainly in the Research phase so the attributed score in relation to the BRETAM model is of 2.

3.2.3 Automotive Industry

To understand better the need for this market, a quick example will be given. When a conductor is driving his car on the highway at a speed of 120 km/h (33,33m/s), an action that takes his eyes off the road (change of radio station or GPS parameter) for 2 seconds would make him go a distance of 66 meters. This scenario could end up in a car crash. Now combine this scenario with the multitude of features available in modern vehicles and the increasing use of mobile phones while driving. Gesture recognition, by allowing the driver to quickly adjust any setting by using certain hand gestures, could help in reducing the risks of car accidents caused by distraction. Major car manufacturers such as BMW and Mercedes-Benz have understood that potential and are introducing some form of gesture recognition technology into their vehicles (Singh, 2019). Given the growing awareness of the benefits of this technology by automotive manufacturers, governments and consumers, the market is expected to grow to more than \$13 billion by 2024 (Markets and Research, 2019). Component suppliers have already begun designing specialized electronic equipment to support gesture recognition in cars (Bhutani, 2020). In 2013, IHS automotive published a report on gesture recognition and proximity detection. According to this organization, the market will grow quite significantly between 2013 and 2023. Figures would rise from 700,000 units in 2013 to more than 38 million in 2023 (Markets and Research, 2019). On top of that, 92 million vehicles were built in 2019 (Statista, 2020). Furthermore, the rate of growth in automotive gesture recognition is over 42% CAGR over the 2018-2024 forecast period (Markets and Research, 2019). This growth is attributed to its use for environmental control applications, vehicle access and other vehicle functionality. Vehicle manufacturers are beginning to install this type of technology in their vehicles to attract consumers and increase market share. All those figures make the automotive industry a real potential market for Guinevere.

Drivers have seen the emergence of new features over the last few years. Major car manufacturers are investing in gesture recognition and therefore believe that drivers are almost ready for this kind of features (Avnet, 2017). As explained, both the market size and the usefulness seem to present positive insights on this technology which attributes a score of 5 for the market demand. On the side of the market offer, those services remains at a certain price which cannot position the technology on the automation phase yet, therefore this is still at the Theory phase which represent a score of 4 on the BRETAM model.

3.2.4 Conclusion

This conclusion will be made mainly through a table showing in the first two columns, the scores of the market demand and the market offer. As a reminder, the market demand

is based on the market size and the usefulness of the technology; and the market offer represents the advances of the technological features necessary to satisfy the market demand. In the last column, the market readiness will be featured as a function of both the market demand and offer. This last column will therefore present the interest of the 7 markets described through this analysis.

The average scores of the **market demand and offer** will be calculated, resulting in a final score, the market readiness. This score will be based on the BRETAM model. The latter corresponds to the level of maturity that a technology will have succeeded in establishing on a market. Theoretically, "*the BRETAM-model describes the sequence of cycles (generations) of an innovation*" (Jaakkola, 1992). For the market offer, the quantification of the score will be from 1 to 6 and done in an ascending order, i.e. a score of 1 represents a breakthrough in the market and a score of 6 represents a mature technology in the market. This weighting represents the strength of each criterion for the market in question. For example, if market x has a size of 5, this means that the size of the market is assessed to be high in comparison to the others.

Market	Market Demand	Market Offer	Market Readiness
Gaming Console	5	4	4,5
Smartphone	3	3	3
Office suite	3	3	3
Smart TV	4	4	4
Operating Rooms	5	3	4
Sign Language	2	2	2
Automotive Industry	5	4	4,5

As this above table shows, the video game market and the automotive industry have a market readiness of 4,5. It should be pointed out that even if those types of markets give more possibilities in terms of demand and offer, the high players concentration makes them less accessible for new entrants and therefore less attractive. As mentioned in the gaming market subsection, the Kinect was a revolutionary product and it did not only involve innovation in the gaming market. It opened opportunities in many markets. The research and development of new application cases has also spread to the world of scientific research, which counts an aggregated number of more than 2700 results about the Kinect in the literature review (and more especially in the IEEE Xplore) as of March 2019 (Guzsvinecz, Szűcs, & Sik-Lányi, 2019). This is the case for the operating room market, which began to use gesture recognition significantly more in operating rooms after Kinect related research were conducted. There are still few players in this market, but its potential is growing, as seen in market demand. This is why our team decided to choose to develop Guinevere in this specific medical market.

3.3 Macro-Environmental Analysis (PESTEL)

To successfully complete this study, an in-depth analysis of the macro-environment is necessary. This can be achieved by analyzing the political, economic, social, ecological, technological and legal context of the target industry, in Belgium. For this, the PESTEL model will be used. At the end of this section, a summary table will highlight the identified variables. Some are a threat (M), others an opportunity (O). Each of them will be assigned a weight of 1 to 10 depending on its degree of influence. On top of that, a scenario planning analysis will be undertaken based on the most influential factors.

3.3.1 Political

Depending on the Belgian and European Governments

The European political context is highly relevant to Guinevere's activities for three main reasons. The first is the creation of a unitary European patent that would allow Guinevere to reduce its intellectual property costs. This unitary creation of a European patent could have a significant impact as the company wishes to file a patent in the coming years. Second, the sectors involved in gesture recognition are subject to numerous European standards and directives that could lead to adaptation costs in the short to medium term. Finally, the free movement of goods, capital and workers between the member countries of the European Union would allow Guinevere to expand geographically throughout the European Union with fewer constraints (Maciejewski & Ratcliff, 2019).

Support for Research and Technological Innovation in Wallonia

The support of the Walloon Region seems very relevant as Guinevere will be based in this region. Indeed, there is a great deal of aid for companies based in Wallonia. For instance, the Walloon Region offers aid for research and innovation that can be applied to any industrial research or experimental development project carried out by one or more firms established in Wallonia. This financial aid can be granted in the form of a grant or a repayable advance, which can cover 40 to 70% of the eligible expenses of an R&D project. Therefore, the Walloon government is trying to help technological projects emerging in the region, which is a positive prospect for Guinevere (Wallonie.be, 2020).

Belgian Health Budget Growth is decreasing

As Belfius (2019) Bank underlines it in a report on the challenges of the health sector in Belgium, all industrialized countries are under pressure on health budgets because of three factors: budgetary targets, an economic slowdown and an ageing population.

In Belgium, the health budget remained relatively balanced between 2011 and 2016,

representing 10% of the GDP. However, it was destabilized between 2014 and 2018 by Charles Michel's government. Indeed, the figures reveal that during these years, the health budget increased by only 1.5%, compared with 4.5% in previous legislatures. In addition to this destabilization, the sector has experienced an overrun in the drug budget of almost one billion euros since 2015. These overruns are not unique to the drug market, as all other health sectors are expected to overspend until 2024 (Belfius, 2019).

Currently, almost 32% of hospitals in Belgium are in deficit. At the same time, the turnover of hospitals amounts to almost 15 billion euros, but only 0.2% of this turnover is a direct profit. This is unfortunately insignificant in the context of a possible budget crisis (Belfius, 2019).

Europe Leads the Way

The EIT health cluster was created within the framework of the European Union. This cluster aims at creating an environment to foster innovation and partnerships in the healthcare sector in Europe. This cluster exists since 2015 and has a budget of nearly 2 billion euros until 2022 (25% from the European Union and 75% from different partners). This cluster also has an accelerator and an incubator at the KUL and IMEC in Belgium. The IMEC incubator alone has 32 start-ups in its portfolio, ranging from the business creation phase to the investment phase. The best-known start-up in their portfolio is Ontoforce (Fabes, 2017; IMEC, 2020).

3.3.2 Economic

Figures Related to Guinevere's Sector

The MedTech sector is booming in Belgium. According to BeMedTech, Belgium has everything it takes to become a real "MedTech Valley" for the following reasons: Belgium has the fiscal framework to support research, the country has internationally renowned specialists, reputed universities geared towards spin-offs, qualified personnel, sufficient management and funding for start-ups and others. Nevertheless, the number of large and medium-sized Belgian MedTech companies is rather limited: Analis, IBA, Orfit, Barco are probably the most famous (MedTech, 2018a).

This industry is divided into 5 different product segments: in-vitro diagnostics (IVD), consumables, implants, medical investment goods (MES) and extra muros solutions, including digital health. In Belgium, these 5 product segments account for some 500 000 different technologies, have an annual turnover of 2.4 billion euros and employ approximately 16 820 people (MedTech, 2018b).

Healthcare Cost on the Rise

In Europe, the cost of healthcare could double by 2050 if no reforms are put in place. This is linked to many factors including rising demographics. Indeed, life expectancy is increasing and the population in Europe is getting older (World Economic Forum, 2020). In Belgium, in 2017, healthcare costs represented 10.24% of the national GDP and this figure is set to rise if no solution is found (World Economic Forum, 2020).

3.3.3 Social

Dependency on Digital

Human beings are spending more and more time on their smartphones, computers and other devices.

Almost everyone in Europe has access to the Internet. In Belgium, 87% of households have access to the internet. This figure is below the European average of 89%. Moreover, 78% of Belgians have a smartphone and 73% of them have a computer. Another important point to note: 100% of Belgian companies own at least one computer. This last figure really helps to understand the extent of the phenomenon. Today, it simply seems impossible to work without a computer (StatBel, 2019).

Figures for Hospital-Acquired Infections

Hospital infections are very common and can affect any patient in a hospital. According to the Federal Center of Expertise for Healthcare (KCE) there are almost 103 000 hospital infections per year in Belgium. In addition, almost 2600 patients per year lose their life as a result of a hospital infection. By way of comparison, the number of road deaths in Belgium in 2017 was 620. On top of that, the prolongation of these infections entails a high financial cost which is estimated at 400 million euros per year (MedTech, 2018a).

Conservatism in the Medical Sector

The medical sector is rather conservative. Indeed, as the article from Health, an entrepreneurial challenge for Europe, underlines it, the medical sector is very complex because there is a certain conservatism: *"When you come in as a start-up with a new treatment for chronic diseases, it means completely changing the existing system with its own logic and financial incentives. The only way to change is to engage in a dialogue with entrepreneurs and decision-makers, especially public decision-makers, to create an open mind. There is very little interaction between the different actors "* (Fabes, 2017). This conservatism was confirmed by Louis-Phillippe Broze and Jean-Benoît Henry, two Belgian starters in the medical world. The latter even described the sector as very corporatist

(Broze & Henry, 2020).

3.3.4 Technological

New Medical Trends

As for new medical trends, there are many of them. As InnovaTech points out, the sector's innovation will be achieved through the digitization of the sector thanks to tools such as big data, artificial intelligence and mobile technologies. Then, thanks to improved diagnostic and imaging technologies, innovation will take place through therapeutic treatments using biomedicines, cell and gene therapies and radiotherapy (Stukkens, 2018).

Belgium's Digital Competitiveness

Belgium finished 25th in the IMD World Digital Competitiveness Ranking 2019, losing 2 places compared to last year and seeing this competitiveness deteriorate for the fourth consecutive year. In addition, France is 24th, Luxembourg is 21st, Germany is 17th and the Netherlands is 6th (FEB, 2019).

Belgium's decline in this ranking is alarming, as digitisation has become a key element regarding competitiveness. A century ago, Belgium was a pioneer of the industrial revolution that laid the foundations of its current prosperity. But in the digital revolution, neither Belgium nor Europe is leading the way. Today, the leaders are the United States and Asia (FEB, 2019).

Personal Technology Advancements

Personal technology is ushering in a new era of healthcare that is fundamentally changing the way medical decisions are made and where treatments are delivered. Thanks to a combination of portable health monitoring technologies, remote medicine, home diagnosis and even self-service retailing, healthcare providers have begun to recognize the importance of treating patients remotely. Since 2014, \$2.3 billion have been raised for digital healthcare start-ups. Between 2011 and 2014, it was \$1.9 billion. Furthermore, 70% of healthcare organizations are expected to invest in mobile medical applications, with an estimated \$1.5 trillion spent on health monitoring technologies and mobile handheld applications. This upward trend in home visits invented by remote healthcare has enabled faster administration of treatment for patients in their homes, thereby significantly reducing the cost of the intervention (Summit, 2017).

3.3.5 Environmental

Impact of Air Pollution on Health

Air pollution is of great concern and has serious health effects in Europe. It contributes one third of death from lung cancer, respiratory issues and other diseases. Today, nearly 9 out of 10 people breathe from a polluted area, which kills about 7 million people every year. It is not only a matter of concern about the quality of outdoor air, but also of indoor air quality, since Europeans spend almost 90% of their time indoor. It is the same health impact as a lifetime of smoking (World Health Organization, 2020).

Impact of Healthcare on the Environment

In the United States, the health sector accounts for 8% of the national greenhouse gas effect. Indeed, if this sector was a country, it would rank 13th in terms of greenhouse gases. In the United Kingdom, the health sector is responsible for 25% of the public sector's carbon footprint. In addition, other factors contribute to the environmental impact of the health sector: the use of toxic chemicals, the dependency towards technology, and the incineration of medical wastes (Santhea, 2018). Furthermore, *"Saving a conservative 40% of potential CO2 savings from anaesthetic gases for four hospitals would be equivalent to 166 fewer cars on the road. Scaling this up to half Europe's hospitals could equate to 300 000 cars"* (Santhea, 2018).

3.3.6 Legal

Patent

In this sector, filing a patent is essential given the fact that this sector has a high technological rate and that a lot of research in the field is carried out every year. As the European Patent Office points out in their statistical table of European patent applications by technological field, the field in which Guinevere's technology is included is called "Medical technology". It ranked third among all other categories of technology, with a total of 13 833 applications in 2019 (EPO, 2019). This underlines the importance a patent can have in the sector in which Guinevere will operate. Nevertheless, a more in-depth study of the patent will be discussed in the Administrative and Legal chapter.

General Data Protection Regulations

This is a European regulation better known as the GDPR. It strengthens and unifies the protection of personal data within the European Union. Its provisions are directly applicable in all countries that are part of the European Union and it is an important regulation to consider for any company. Indeed, Guinevere will have to take this regulation

into account from the very beginning in order to comply with it (Intersoft Consulting, 2020)

3.3.7 Summary Table of the PESTEL Analysis

The PESTEL factors are organized in the following table. Some of these factors represent a threat while others are an opportunity. In addition, those factors' weight are also given in this table.

Factors	Threat	Opportunity	Weight (1 à 10)
Depending on the Belgian and European government	X		6
Support for research and technological innovation in Wallonia.		X	6
Belgian health budget growth is slowing down		X	9
Europe leads the way		X	8
Figures related to our sector		X	9
Healthcare cost on the rise		X	7
Dependency on digital		X	6
Figure for hospital-acquired infections		X	9
Conservatism in the medical sector	X		9
New medical trends		X	7
Belgium's Digital Competitiveness		X	6
Personal technology advancements		X	6
Impact of air pollution on health	X		6
Impact of healthcare on the environment	X		7
Patent	X		7
General Data Protection Regulations	X		7

3.3.8 Scenarios

	Sector figures continue to rise, and more and more investments are being made in the sector.	Figures in the sector are stagnating and there is less and less investment.
The health budget is increasing to a growth rate of over 1.5% in order to catch up with the overruns in the various sectors.	Scenario 1 The sector is very thriving and on top of that the health budget is increasing.	Scenario 2 The sector is less attractive, and the health budget is increasing.
The health budget is decreasing and stagnating at 1.5%.	Scenario 3 The figures for the sector are very positive and the current legislature is granting a budget that is too low.	Scenario 4 The health budget is still unable to make up for the various overruns and our sector is in the middle of a decline.

Figure 3.4: Scenarios

Scenario 1: The sector is very thriving and on top of that the health budget is increasing.

The sector is becoming more and more prominent, it is attracting many Belgian and foreign investors. The Guinevere company will probably be able to count on private investment and consequently develop faster. Moreover, this context will increase the number of companies on the market, which will probably result in an increase in the number of competitors, both direct and indirect. This context will have clear strategic consequences: intensification of competitive intensity, war between the main companies in order to impose their technological standards and prices. As far as the increase in budget is concerned, it will have the effect of increasing the budget of hospitals (Guinevere's main customers), which would make the product sale's much easier. In order to counteract the strategic consequences due to a flourishing sector, Guinevere will rely heavily on its good relationship with hospitals but also on its reputation and communication.

Scenario 2: The sector is less attractive, and the health budget is increasing.

The context of the sector is negative, which means that few companies are on the market and therefore competition is not intense. In addition, less investment is available

which will slow down Guinevere's progress but also of the sector. Nevertheless, the hospital sector will have a higher budget than previously. The company will mainly have to set up a first partnership with a hospital, in particular via the UCLouvain, which has two different clinics. If a partnership is not found, the company will still be able to turn to a sector whose economic context is more favorable as depicted in 3.2.4.

Scenario 3: The figures for the sector are very positive and the current legislature is granting a budget that is too low.

The positive economic context is favourable for all companies already active or wishing to enter the market. This will lead to increased competition as well as increased investments. On the other hand, the budget granted by the state to hospitals is stagnating and hospitals are increasingly in difficulties. As a result, they cannot afford to buy Guinevere's solution. One of the options Guinevere will consider is to set up in one of Belgium's neighboring countries where both the budget for hospitals and the figures for the sector would be positive. Countries such as France, Germany and Sweden could be considered as they have the highest health expenditure relative to GDP in 2016 (between 11 and 11.5%) (Eurostat, 2019).

Scenario 4: The health budget is still unable to make up for the various overruns and the sector is in the middle of a decline.

If both the economic context of the sector and the budget of the current legislature are weak, this will have disastrous consequences for the Guinevere company, which would probably not be able to sell its solution and will have no choice but to change its sector of activity.

3.4 University Spin-off

According to the Louvain Technology Transfer Office, university spin-offs are commercial companies whose incorporation involves the transfer of the results of research carried out at UCLouvain and the related intellectual property rights (e.g. know-how, patents, software, databases, trademark, copyright, etc.) (Bovy et al., 2012).

Furthermore, UCLouvain, via the Louvain Technology Transfer Office, has been involved in the launch of 76 spin-offs from 1986 onwards, 65 of which are still active today. These start-ups are operating in a wide range of fields of innovation, from life sciences to digital technology, nanotechnology, biomedical sciences, robots, energy, food industry and business services (LTTO, 2019).

Before starting writing this thesis, we were asked to make an assignment of rights in order to guarantee a certain homogeneity between what had been developed in the Gestus

code and what the four founders were going to develop on their side. Therefore, if the founders want to create a company based on the results they obtain from their CPME thesis, it will be de facto a spin-off company since it will be based on results coming from the University's laboratories (Dumonceau & Palate, 2020).

3.4.1 Advantages of Being a Spin-off

As it will be described throughout the description of the creation process of a spin-off from UCLouvain, the LTTO will provide guidance to Guinevere. This is a real advantage as the project will have an outside viewpoint but also an expertise that the team do not particularly have in terms of intellectual property (Dumonceau & Palate, 2020).

Another advantage is the fact of having a label from the university and being backed up by it. This is an advantage most start-ups do not have. Indeed, creating a company based on intellectual property coming from a university that has a certain reputation, is a guarantee of certain quality, regarding both customers and investors. Also, the university could open the access to public financial support, through first spin-off funds for instance (Dumonceau & Palate, 2020).

Moreover, as Christophe Dumonceau pointed it out, a spin-off has the advantage to benefit from a framework. It is the LTTO's mission to support first spin-off projects. For example, the LTTO can help get in touch with partners such as hospitals and clinics. According to him, there is another benefit in being associated with UCLouvain, which is to be able to potentially test Guinevere's concept in operating rooms, since the university has two clinics with such facilities (Dumonceau & Palate, 2020).

Finally, another advantage is the Sopartec's existence, the UCLouvain technology transfer company, which manages an investment fund. It may be inclined to invest in spin-off projects from the university because it knows them and knows their potential (Dumonceau & Palate, 2020).

3.4.2 Disadvantages of Being a Spin-off

Whoever says intellectual property of the university says it is transferred. Generally speaking, Guinevere will have shares that will belong to the university and a licensing agreement on this intellectual property.

As Christophe Dumonceau told it: *"It's all a matter of strategic choice. You have the option of being 100% in control of your company, but it may be more difficult to raise capital or to actually enter the market. And then, the other option is to be diluted from the outset but to be backed up and have the help of UCLouvain with the possibility of finding other investors later on who would buy back the shares initially acquired by UCLouvain."*

3.4.3 Conclusion

Following a meeting with Christophe Dumonceau and Matthieu Palatte, it seems clear that having signed the papers concerning the transfer of our rights, we have no other choice but to create a spin-off. Moreover, by creating a spin-off, we will potentially benefit from access to UCLouvain's operating rooms but also to the clinics and potential partners that the University has developed over time.

3.5 Porter's Five Forces

3.5.1 Industry Rivalry - Direct Competition

Johnson (2014) explains that competition occurs when similar services are offered on a market. In this section about the industry rivalry, which is to say the direct competition, a description of each of the competitors will be provided, followed by an in-depth analysis to highlight the factors of success and failure.

TedCas

TedCas is a Spanish company and seems to hold a leading position in Guinevere's target market, as it focuses solely on gesture recognition in operating theatres. It also has the largest number of employees (9 according to LinkedIn) and a strong online presence (Tedcas, 2020; LinkedIn, 2020).

TedCas uses both touchless gesture recognition and voice commands to navigate through the patient's medical images. Their software is embedded in a hardware and together they are sold as the TedCube. On their website, they claim that their software is "compatible with all reputable sensors on the market" such as the Myo armband, the Leap Motion, the BlasterX Senz3D or the Plantronics Voyager Legend UC. This is a tremendous advantage over other companies that rely on a single sensor, such as the Xbox Kinect for example (Tedcas, 2020). The company also sells two other health-related products:

- **Augmented Reality Presentation:** This product is aimed at helping professors teaching surgery to provide real-life examples of surgery cases embedded in a PowerPoint presentation (Tedcas, 2020).
- **3D Imaging:** As TedCas' services are compatible with multiple hardwares such as the HTC Vive, the Oculus Rift, the HoloLens or the DAQRI, they allow their clients to visualize medical data with those headsets, which gives access to a much clearer spacial visualization (Tedcas, 2020).

On its website, three surgeon's testimonies relating the usefulness of their product are featured. A video of a live surgery also shows them using the solution. On top of that,

the price of their solution is €3000 per year (Tedcas, 2020).

aeroTAP

Part of the nextEDGE Technology group, aeroTAP is a Japanese company. Rather than using existing sensors available on the market, aeroTAP has developed its own: the aeroTAP 3D GS. Its core business focuses on the endoscopic surgery navigation. The company is also in collaboration with the University of Tsukuba Hospital.

The interesting aspect about this company is that it focuses not only on the medical field, but on gesture recognition in all sectors. The company offers solutions in bureaucratic, in signs recognition and also code for developers so they can create their own gesture recognition applications. As a result, their field of action is much broader than Guinevere's.

The aeroTAP 3D GS can be integrated only under the Windows operating system. For medical purposes, the aeroTAP Camera and the aeroTAP Evolution Pro license are necessary and cost a total of \$500. They also offer a non-commercial use for \$225 and a shipping fee of \$30 as it comes from Japan. Consultancy to help the surgeons to accommodate themselves can also be given as a service. Following an interview that was conducted for this thesis, here is an extract of aeroTAP's answers:

"We also provide fee-based consultant service to customize aeroTAP Evolution settings for their DICOM system. It is simple customization to add some virtual buttons for Display Scrolling or Mouse Wheel actions. Maybe you can handle such service and locally once you understand aeroTAP's assistant features (virtual buttons)".

KiOP- Kinect in OPerating Room

This project was led by the Geneva University Hospitals. Professor Osman Ratib, one of the three founders of the famous DICOM viewer OsiriX (2020) that runs on MacOS, represents the multidisciplinary team - medical and IT - behind the KiOP project. Several researchers had created plug-ins incorporated into this DICOM, like the company Virtopsy (Virtopsy, 2011). This shows the competitive advantage that KiOP holds by having the professor Ratib aboard as he is well involved in the medical images information management. The Geneva University Hospitals also created the DICOM viewer Weasis, which runs on Windows. The KiOP team develops a solution for both operating systems (Wipfli et al., 2016a).

Furthermore, KiOP decided to use the Kinect as a sensor:

"It has been chosen because it has sufficient precision and response time, is low cost, and is well-documented, and provides a programming interface" (Wipfli et al., 2016a).

KiOP counts several differences with the other competitors. As the KiOP team wrote

in their research paper, their project is non-commercial. The company opted for an open-source software like OsiriX, which suggests they could be seen as a potential ally. Secondly, even if the Kinect of XBox allows voice recognition, the KiOP software does not integrate this parameter as they considered that gesture overtakes voice recognition:

“Voice control was significantly slower than touch panel control and relaying a third person. [...] Finally, voice control suffers low reliability when non-native speakers use the recognition engine”(Wipfli et al., 2016a).

However, the research paper “Voice or Gesture in the Operating room” would contradict this decision as they see the two as complementary (Mentis et al., 2015).

GestSure

This is one of the first company that brought gesture recognition in operating rooms, with a solution to control medical images in DICOM format. The difference with TedCas and aeroTAP is the fact that GestSure operates in the healthcare is now to be very expensive. According to a study of Health System Tracker, the average total health expenditures per capita in the USA is of \$10 348 compared to \$4 840 in Belgium (Kamal & Cox, 2018).

The gesture recognition solution in operating rooms reduces the time necessary to perform surgery. In the USA, operating faster leads to costs reduction. In a 2015 video, Jamie Tremaine, known as the CEO of GestSure, stated that a minute in the operating room costs on average \$62 and that their solution could allow a discount of \$500 per surgery (GestSure, 2015). By comparison, a minute in an operating room in Belgium costs about €11 (KCE, 2009).

GestSure was integrated in the Microsoft Kinect Accelerator hosted by TechStars. Microsoft also supported GestSure financially as they received \$20 000 in funding and \$60 000 in Azure credit. GestSure even appeared in the 2014 Super Bowl ad of Microsoft (FledThoughts, 2012). Furthermore, a Microsoft Research Cambridge team collaborated with GestSure.

However, despite all this support, Bill Gates’ company stopped the research on gesture recognition, and this has had a negative impact on GestSure as since 2016 the company shows no sign of activity on their networks and no press articles are mentioning the company.

STS – Progesoftware

Progesoftware is an Italian company that focuses on the development of IT solutions for small and medium enterprises, with services like cloud adoption and data governance

compliance. In 2015, the company developed a project called STS (Surgery Touchless System) (ProgeSoftware, 2015). It does not require any particular hardware, only a laptop, a screen, and a Kinect. The company works in collaboration with the "Universita campus bio-medico di Roma" and a scientific article was written to assess the software.: *A Touchless system for image visualization during surgery: preliminary experience in clinical settings, 2018* (Massaroni et al., 2018).

This solution is just one of many which the company offers. It is not their core business. An attempt was made to gather more information on their products, but since Covid-19 is currently hitting Europe, they did not have the time to provide us with any further useful information.

Direct Competition's Conclusion

Following this analysis, TedCas and GestSure are the two players that stand out in terms of implementation on the market and the customers they have. In 2013, Jesus Miguel Perez, CEO of TedCas, presented his project at a Wired conference (Perez, 2013). Two years later, Jamie Tremaine presented his project at the IoT and Health Expo (GestSure, 2015). Today, however, only TedCas remains active on the market.

As it can be seen in the table below 3.1, both companies initially used the Kinect sensor. GestSure even had an advantage over its competitors as it was championed by Microsoft and its solution was even featured in the first Microsoft Super Bowl advertisement. However, in 2017, Microsoft announced the Kinect's end (Comstock, 2017). While TedCas seemed interested in other types of sensors, GestSure was putting all its efforts on its partnership with Microsoft. One hypothesis seems to be that this supplier relationship has had a negative impact on GestSure's business and has affected all of its internal processes. TedCas was able to bounce back after the Kinect disappeared and today their solution is available for more than 4 different sensors. Other competitors such as KiOP and STS Progesoftware were dependent on the Kinect and are no longer showing any sign of activity, leaving TedCas as Guinevere's last direct competitor.

Because most of the scientific literature on gesture recognition has been written by Microsoft researchers, many companies decided to use the Kinect as their sensor. Indeed, the proportion of scientific articles using the Kinect is clearly higher than other existing sensors (Guzsvinecz, Szűcs, & Sik-Lányi, 2019). Despite the fact that alternatives such as the Leap Motion and the Intel RealSense+Nuitrack are equivalent solutions.

How could the disappearance of the various market players be explained? A hypothesis would be the end of the Kinect, even though the gesture recognition technology seems very promising for operating rooms.

Here are some facts that support this hypothesis:

- Released of the Kinect in 2010
- In 2011, Microsoft is launching a Microsoft Research team on the development of Kinect in operating rooms. Professor Gonzalez - part of the Microsoft Research team - told us that Microsoft totally stopped its research after 2 years, and the scientific articles stopped as well.
- TedCas, GestSure, Progesoftware, KiOP launched their projects after 2011 and initially **all** used the Kinect. In 2017, Microsoft announced the commercialization of Kinect will end. Today, only TedCas seems to have survived, despite a promising market demand.

As a result, competition on this market, particularly in Belgium, is low. This will give Guinevere some price-flexibility and therefore a potentially higher profit.

	TedCas	aeroTAP	KiOP	GestSure	STS
Year of creation	2011	2006	2014	2011	2015
Country	Spain	Japan	Switzerland	Canada	Italy
Partnership with hospital	At least 1				
Technology	TedCube	AeroTap 3D GS	Kinect	Kinect	Kinect and pedal
Compatibility	Plug and Play	Plug and Play	Only OsiriX and Weasis	Plug and Play	?
Core business	Touchless control in OR	Sensor devices development	Touchless control in OR, research based	Touchless control in OR	Delivering multiple IT solutions
Competitive Advantage	Well present on the market: +30 customers	Cheap solution	Professor Osman, co-founder of OsiriX	Support of Microsoft, figured in their 2014 Super Bowl Ad	Pedal system
Voice & Gesture recognition	Both	Gestures only	Gestures only	Gestures only	Gestures only
Cost	€3000/year	500 USD fix price + cost of consultancy	Not commercialized	1000 USD/monthly	?

Table 3.1: Competition table summary

3.5.2 Bargaining Power of Suppliers

There are not many resources required for Guinevere's product and therefore not many suppliers either. Since the company would mainly provide a software, the gesture recognition algorithm related to it will be Guinevere's main competitive advantage. Second, a sensor will be necessary in order to detect the gestures being performed.

Concerning the sensor, there are very few suppliers that can meet Guinevere's needs. Therefore, the bargaining power of those suppliers would be high and their negotiation will play a crucial role in the success of the company. The risk of being subject to relatively high prices is therefore high as well. In order to counter this problem, the choice of the sensor will be made towards the most adopted one on the market. Guinevere has decided to use the Leap Motion as its first supplier but may partner with others in the future. That choice will be further developed in the product section 4.

A great example of bargaining power of suppliers is when Microsoft decided to stop selling the Kinect, which had an important impact on the existing businesses relying on it.

3.5.3 Bargaining Power of Buyers

The target Guinevere is aiming at is Belgian hospitals with one or more operating rooms. According to the report made by Health Belgium in 2012, there are 104 hospitals with at least one operating block in Belgium and therefore there are 104 potential customers that could be targeted. However, these figures should be taken with a pinch of salt, since the report was made in 2012 and other hospitals with operating theaters may have been built or closed since then (Health Belgium, 2015).

In Belgium, there is no solution similar to Guinevere's. It is therefore a relatively unexplored market, which is likely to be challenging to penetrate. Moreover, it is a highly innovative technology that will be difficult to adapt to the market and to surgeons. It will therefore be essential to convince them by all means that this solution is effective. Guinevere will be the pioneer in Belgium, but this could evolve in the years to come, which is why it is important to establish strong relationships with hospitals to minimize the risk from substitutes and potential competitors. In conclusion, bargaining power is high because even if there is no real alternative on the market. The usefulness of the solution remains to be proven by the Guinevere.

3.5.4 Threats of Substitutes

"Substitutes are products or services that offer an equivalent benefit to customers, but with a different approach" (Johnson, 2014). In other words, indirect competitors are other players in the market who meet the same need that Guinevere meets, but with a different

service or product.

According to Levitt, companies should focus their efforts on the need they are addressing with their solution, which gives a much broader view of the competitive environment (Levitt, 1960). In Guinevere's case, the company is fulfilling the need for a sterilized operating room environment and a decrease in the time spent in the operating room, which implies a reduction of costs for hospitals.

Actual Situation

In operating theaters, the most common way to ensure navigation through the patient's medical data, and preserve the surgeon's hands sterility, is to require the assistance of a nurse that proceeds according to the doctor's instruction. This can lead to misunderstandings and increased operation time. Here is a response coming from a surgeon, that confirms the statement made in the previous lines:

"On doit demander à l'infirmière ou à l'anesthésiste de faire défiler les images si l'on souhaite les passer en revue, pareil pour enregistrer l'opération " as explained in appendix E.0.5.

There are also cases where surgeons need to navigate the medical data themselves. Two options are possible:

- The latter has to step away, take his gloves off, take the information he needs, then sterilize his hands again, put the gloves back on and get to his operating table. This adds a significant amount of time to the surgery.
- Another way is for surgeons to "flick their surgical gown over their hands and manipulate a mouse through the gown. The rear of the gown, which is non-sterile, touches the mouse (also non-sterile) while the front of the gown and the hands, which are sterile, remain separated from those surfaces" (O'Hara et al., 2014).

In conclusion, these three situations are not ideal for the patient because they compromise sterility and waste precious time, which leads to increased costs for hospitals.

Indirect Competition

Sterile Mouse and Keyboard

In some less invasive surgery cases, it is possible to use special keyboard and mouse sterile covers. The keyboard is then completely flat to avoid the little gaps between the keys, in which bacteria can easily spread. However, all bacteria cannot be avoided and this kind of keyboard is not as easy to use as a traditional one. In addition, these tools have to be washed after each patient, which results in additional costs (Fukada et al., 2008).



Figure 3.5: Flat Keyboard (Fukada et al., 2008).

Voice Recognition

Like gesture recognition, voice recognition was also deemed appropriate to use in operating rooms, as it could be a potential solution to the sterility issue. As explained in the article *Voice or Gesture in the operating room*, there is not one technology better than the other, but they complement each other and are to be used in different situations. Guinevere mainly tackles gesture recognition in order to control medical images in operating theaters, but voice recognition might be looked into in the future. However, in terms of quality and technology, voice recognition is much more difficult to implement because it is less accurate and requires more advanced equipment. This is the main reasons why we focused on gesture recognition and not on voice recognition (Mentis et al., 2015).

Remote Surgery

Robotic surgery is increasingly used throughout the world. The most common system is a mechanical arm to which surgical tools are attached, combined with a camera arm. Surgeon control those arms remotely with the help of a computer. In addition, surgeons can give instructions to their entire team, which assists them during the operation. This technology has many advantages: it improves precision, flexibility and control. This method can allow the execution of operations that could otherwise be difficult or impossible to perform. It also drastically reduces the risk of infection, which makes it a serious competitor since this is the problem we want to address (Mayo Clinic, 2020). This technology would be much more efficient than Guinevere's value proposition. Nevertheless, its price is extremely high, which could slow down the growth of its distribution. In addition, the technology is much more advanced, which requires much more training for surgeons who might therefore be more reluctant to adopt it, in comparison to Guinevere's solution.

Microsoft - HoloLens

Despite to the end of the researchers with the Kinect, Microsoft seems to still be involved in the surgery research through touchless gesture recognition. However, those researches are not made with the Kinect anymore, but with the HoloLens (Microsoft Reporter, 2018). The approach is quite different from the one depicted earlier. Rather than having the 2D medical images displayed on screens in the operating theater, the patient's images are directly represented on him, in 3D.

This device makes it easier for surgeons to operate as they have the information directly in front of them and not on a screen at a certain distance. The advantage of sterility is still there as the navigation is done through hand gesture and voice recognition. The square shown in the image ?? on the right above gives a cut-off image of the organ. Depending on the orientation used, a different inner part of the organ will be visible. One of the examples of companies developing this technology is the German company apoQlar which has developed a software called VSI (Virtual Surgery Intelligence). This software enables the use of this application with HoloLens. This technology is quite new and its commercialization has only just begun, since they sold their solution on February 12, 2020 to the Asklepios Clinic in Altona. (apoQlar, 2020).

Conclusion

As discussed in this section on indirect competitors, there are currently some substitutes for Guinevere. However, most are technologically more challenging. In addition, given the conservative nature of the medical industry, such innovations will take time to be embraced. As a result, the threat from substitutes is moderately high.

3.5.5 Threat of New Entrants

The degree of threat from potential entrants depends on four types of barriers: financial, commercial, resources and skills (Johnson, 2014).

Financial Barrier

First of all, if a similar project wanted to get off the ground, it would not necessarily benefit from the same kind of help Guinevere received so far. This could lead to a relatively large upfront investment for the outsider. Furthermore, the very specific technological character of this project requires a great deal of knowledge in the field and could require a lot of research and development for companies wanting to enter the market.

Commercial Barrier

Concerning the trade barrier, Guinevere is the first to launch this type of product on the Belgian market. This should enable it to take benefit of the first mover advantage and

to rapidly expand its customer network, which will mainly be made up of hospitals with operating theaters. In addition, the company will aim to be a spin-off, which could enable Guinevere to have a privileged relationship with certain hospitals, in particular those of UCLouvain.

Resources Barrier

The software will be patented to protect Guinevere from its potential competitors. This will be a real barrier to entry since any company wanting to use a software that comes close enough to Guinevere's will have to pay a license fee or will be prohibited from doing so.

Skills Barrier

The time it would take to reproduce a similar technology is very substantial. Researchers around the world have been working for years to improve the algorithms already on the market. Moreover, thanks to CPME, the whole team is multidisciplinary which allows a good complementarity but also an advantage over Guinevere's competitors as soon as they are launched.

3.5.6 Conclusion

The graph below is called the Porter Sector Hexagon, which represents the 5 Porter Forces and the Government's role established in the PESTEL analysis presented earlier. This makes it possible to directly detect whether the industry under study is attractive or not. The less its form is extended, the more attractive the studied market is. In the present case, the sector in which Guinevere should enter is fairly attractive.

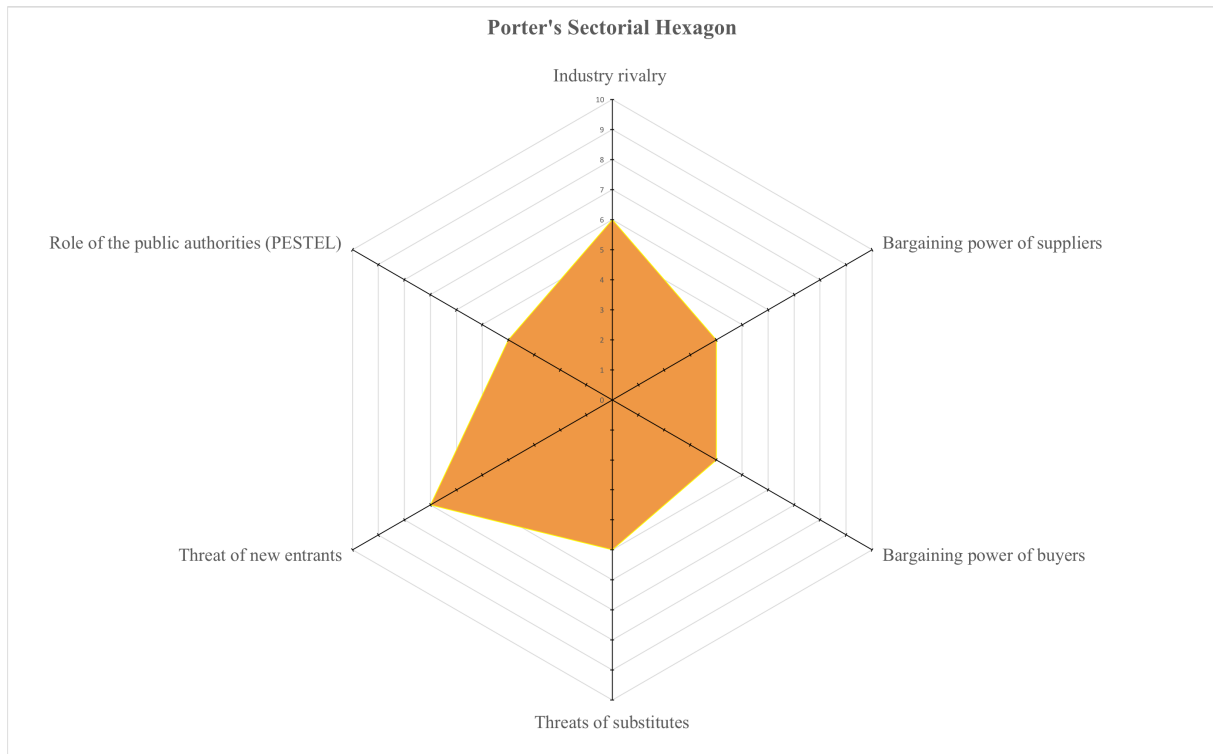


Figure 3.6: Porter's sectorial hexagon

3.6 Bowman's Strategic Clock

This strategic analysis is different from Porter's five forces. The latter is distinguished by two important elements. First, the market orientation by focusing on price and perceived value. Second, by its circular shape which implies greater flexibility than Porter's model (G. Johnson, Whittington, Scholes, Angwin, & Collectif, 2017). Concerning Guinevere, working on its competitive position will be crucial to differentiate it from its direct competitors already operating on the global market. The advantages of Guinevere's solution are related to its quality, which is the improvement and the allowance of surgeons to be able to operate faster thanks to a vectorial algorithm. As the operation will be done faster, the surgeons' labor costs will be reduced. This can place Guinevere as an upgrade of the current solutions for controlling medical images.

The differentiation strategy implies a high perceived value by a product's customers. In order to build surgeons' trust, conclusive results are crucial. Guinevere is privileged to be based in a university environment. The solution therefore grows in credibility since UCLouvain has already experienced successful spin-off projects, with IBA and IRIS for example (Hôpital Saint Luc, 2020; CHR, 2020). In addition, the university has the advantage of owning the Saint-Luc clinic and the CHR of Namur (UCLouvain, 2019). Having such a partner also enhances the trust of the public since it becomes implicit that the product was developed in collaboration with professionals of the sector.

As a conclusion, Guinevere could be placed at a differentiation position:

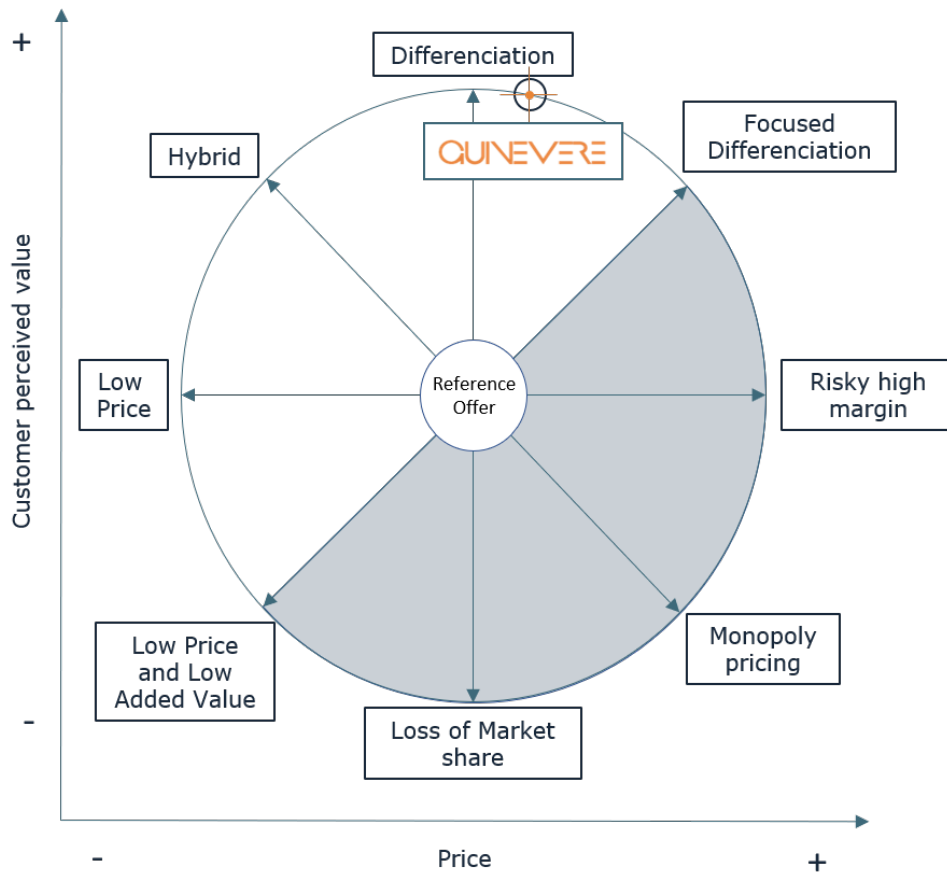


Figure 3.7: Bowman Clock

3.7 SWOT Analysis

3.7.1 Strengths

In contrast to direct competitors, most of whom have only scientists in their companies, which could be problematic in terms of strategy or communication, Guinevere's CPME team has a wide set of specific skills. The impact on performance and the degree of importance of this first factor is high. As it was regularly explained throughout the CPME curriculum, one of the success factors of a startup is its team. Guinevere has also a unique algorithm that could be its competitive advantage. This same algorithm could lead to a patent application in the form of a software. This strength is judged as high in terms of importance and high in terms of performance.

Guinevere is the only company in this sector that has its headquarters in Belgium, which will definitely be an advantage when tackling the Belgian market. On top of that, Guinevere aims to become an UCLouvain spin-off, which may allow the company to access

hospitals more easily. The UCLouvain owns CHU Dinant Godinne - UCL Namur and Cliniques Universitaires Saint Luc - UCL. The latter is spread over three different sites in Dinant, Godinne, and Sainte-Elisabeth and represents 37 operating theaters. The second has 28 operating theaters and a Da Vinci surgical robot. In addition, this University has created the Louvain Health Network which is composed of 25 partners who could all be target customers for Guinevere. Following these figures and the fact that there are still no competitors on the Belgian market, this factor will have a high degree of importance and a major impact on performance. It will therefore be essential for Guinevere to find agreements with Belgian hospitals and specifically those of UCLouvain.

3.7.2 Weaknesses

Having less experience than the competition could happen to be a real obstacle. Only Tancrede and Jean have already had professional experiences. In order to reduce this weakness as well as possible, the team tried to surround itself as well as possible, mainly with promoters experts in different fields and a mentor specialized in entrepreneurship. This factor will have a major impact on the performance of Guinevere and a high degree of importance.

A second weakness is the lack of equity. Considering the team's young age, personal assets remain limited. External sources of financing will have to be looked into and this could make Guinevere dependent on those external actors who will have financed the company. This factor will have a major impact on performance and a high degree of importance. The third and final weakness is the team's lack of knowledge of the medical sector. The latter is an extremely difficult market to grasp. Moreover, the team lacks a medical profile. This weakness is considered to be of high importance and to have a high impact on performance.

3.7.3 Opportunities

One of the real opportunities is the fact that, as BeMedTech points out, the sector is booming in Belgium. As already explained in the PESTEL analysis that figures in the subsection 3.3, Belgium has everything to become the MedTech valley: the country has a fiscal framework that favours research, it has renowned specialists, extremely reputable universities, qualified personnel, money to invest in start-ups. Nevertheless, this opportunity should be seized quickly because this environment is the same for any other company wanting to start in this sector. For the moment, no competitors are established in Belgium, which is why the above opportunity seems very real. This factor has a high probability of occurrence and a high impact as well (MedTech, 2018a).

At a time when machines are increasingly replacing humans, it seems that the market

is ready for this kind of innovation. In addition, as our online questionnaire (see appendix E.0.5) points out, some surgeons have found Guinevere's product interesting and might be willing to try it. This shows a real interest coming from the market. Competitors who arrived much earlier on the market may have been unlucky in terms of timing and arrived too early on a market that was not ready for this type of technology. Nevertheless, it is very difficult to verify this information, which is why this factor is considered to have a medium probability of occurrence and a high impact.

3.7.4 Threats

Corporations such as Microsoft and Google are active on the market. If those giants were to launch a product similar to Guinevere's, this could mean the end of the company. It is therefore necessary to take all possible measures to protect Guinevere from such an event by trying to move forward with the project as quickly as possible but also by avoiding disclosing sensitive information. This factor will have a medium probability of occurrence and its impact will be high.

As seen in the PESTEL analysis in the subsection 3.3 the budget allocated for hospitals is steadily decreasing. It will be a matter of seeing if the hospitals will have the necessary budget to procure our solution. The current uncertain Belgian political situation and the context of the world in general must also be taken into account. The world is currently being hit by the Covid-19 pandemic, which is endangering Guinevere for various reasons. First, because the world in general and Belgium are going through a difficult socio-economic period, it is not optimal to launch a company in this kind of situation. Moreover, Guinevere's target market is being hit hard by this pandemic, since it is the medical sector, which will considerably delay Guinevere's progress. This factor has a high probability of occurrence and a high impact as well.

3.7.5 SWOT Summary

STRENGTHS • The (complementary) team (S1) • Tracking strategy (S2) • Technological Advantage (S3) • Belgian Market (S4)	THREATS • Potential entry of a direct competitor (T1) • Hospitals lack budget in Belgium (T2) • Current Context (T3)
OPPORTUNITIES • Booming Belgian market (O1) • The market seems ready (O2)	WEAKNESSES • Lack of experience (W1) • Lack of funds (W2) • Lack of market knowledge (W3)

Figure 3.8: SWOT analysis

3.8 TOWS Analysis

Although this matrix is less popular than the other strategic tools used earlier, it seemed relevant to complete the TOWS analysis. Indeed, this matrix is based on the results of the SWOT analysis and allows to develop strategic alternatives that combine internal and external factors.

	STRENGTHS	WEAKNESSES
	• The (complementary) team (S1) • Tracking strategy (S2) • Technological Advantage (S3) • Belgian Market (S4)	• Lack of experience (W1) • Lack of funds (W2)
OPPORTUNITIES	Use strengths to seize opportunities	Seek to use opportunities to minimize weaknesses as much as possible.
THREATS	Use the forces to protect themselves from threats	Minimize weaknesses to avoid threats

Figure 3.9: TOWS analysis

3.8.1 Strengths - Opportunities (SO)

In this section, the following question will be covered: How can we use our strengths to take advantage of existing opportunities?

As stated in the SWOT analysis, the Belgian market is booming (O1) and faced with this opportunity, Guinevere's major advantage is to be based in Belgium, stemming from a Belgian university which has two clinics and therefore operating rooms (S4). As the only Belgian company on the market, taking advantage of this opportunity (booming market) may be easier to achieve.

The complementary team but also competent support in different fields (S1) is an advantage as well. In addition, a lot of information regarding competition was collected. On top of that, Guinevere has a technology that is still new on the market (S3). All these elements will enable the company to file a patent but also to become a spin-off in order to have access to the operating rooms of the UCLouvain clinics. This will allow to test the market but also to receive financing more easily and probably earlier in Guinevere's development. We will therefore be able to quickly judge whether the market is as ready as we think it is (O2).

3.8.2 Strengths - Threats (ST)

In this section, the following question is addressed: How could we use our strengths to minimize (potential) threats?

As previously explained, Guinevere's team is complementary. This specificity could allow Guinevere to keep an edge over the competition and even over new entrants (S1). Moreover, thanks to Guinevere's technology and the filing of a patent (S3), the company will be protected from competitors who may wish to use it. This would be a high barrier to entry for future entrants (T1). Filing a patent and being attached to a university such as UCLouvain will allow Guinevere to gain a degree of credibility which will in turn probably convince hospitals to put money into this solution even though their budgets have been declining since 2018 (T2).

3.8.3 Weaknesses - Opportunities (WO)

In this section, the following question is addressed: How can we put the opportunities at the service of our company in order to overcome our weaknesses?

As already mentioned, several times, the Belgian medical technology market is booming, which is an interesting opportunity for investors. Therefore, raising capital in order to compensate the team's lack of funds could be a possibility (W2). Funds that UCLouvain makes available to spin-offs are also an option, as well as subsidies that are available for the medical sector (O2).

3.8.4 Weaknesses - Threats (WT)

In this last part of the TOWS, the following question is addressed: How can we minimise our weaknesses in order to avoid or minimise (potential) threats?

The team's lack of experience (W1), the limited funds (W2), and the lack of market knowledge (W3) could very quickly prove to be a real challenge. Nevertheless, Guinevere's big advantage is to be a small, flexible, and agile structure. Guinevere will be able to adapt quickly to the possible evolution of its market as well as react to the feedbacks that will be given by the surgeons.

3.9 Business Model Canvas

Osterwalder and Pigneur (2010) have designed the Business Model Canvas (BMC), a tool that depicts the company as a whole and highlights elements that can represent a competitive advantage for current market players. In addition, identifying a business model will allow assessing the feasibility and profitability of a project (Janssen, 2016).

Therefore, in this section, the 9 components of the Business Model Canvas are applied to Guinevere in order to define and assess its key resources compared to competition. Moreover, this section will help in summarizing Guinevere's specific features when the project will have to be shared with various stakeholders (Bocken, Short, Rana, & Evans, 2014).

3.9.1 Value Proposition

The solution delivered by Guinevere aims to solve a widespread sterility issue in operating rooms. Indeed, before a surgery starts, surgeons need to proceed to a hand rubbing under a strict methodology. According to the World Health Organization, three hands rubbing exist: 3, 5 and 10 minutes. The most recommended is the 5 minutes one (World Health Organization, 2009). Once done, the surgeons' hands can only enter in contact with the patient and sterilized tools. If they want to access medical data through a computer, they need to proceed a second time to the hand rubbing procedure as the keyboard and the mouse of the computer cannot be fully sterilized. An alternative is to require the help of a medical staff member to navigate the data. However, many surgeons shared that this is not as effective as if they were doing it themselves and it increases the time of the operation as well as operation costs for hospitals (O'Hara et al., 2014).

This time loss involves frustration for the surgeon, but it also has important consequences such as:

- The surgeon fatigue can lead to medical mistakes. An open-heart surgery can last 3 to 6 hours (Weiss & Parzz, 2017). During a long period of focus, surgeons are affected by tiredness and lack of attention, which can lead to mistakes endangering the patient's health.
- Since access to medical data adds extra time to the operation, this lack of efficiency results in a financial loss for the hospital. Reducing the length of a surgical procedure would reduce the number of hours supplied by surgeons, resulting in lower costs for hospitals, which is useful when we are aware that hospitals in Belgium are actually financially struggling due to a lack of budget.
- Finally, the most important value that Guinevere offers is the autonomy granted to surgeons as they can access medical data without any sterility-related constraints.

3.9.2 Customer Segments

The customer segmentation will be useful because many players in the hospital landscape are involved in Guinevere's purchasing process. In the following lines, all decision-makers that may have an impact on Guinevere's sales are discussed (Janssen, 2016).

Heads of Surgery Services

Vascular surgery and neurosurgery are the departments that most benefit from touchless navigation through medical data (R. Johnson, O'Hara, Sellen, Cousins, & Criminisi, 2011). Reaching these department heads' would be a major asset as they have a team of surgeons under their supervision. They can have influence on the unit's management and thus have an influence on the decision-making process. They are also a contact point with other hospitals because they own an extensive network. In addition, they know the habits of the surgeons because they have to supervise them and know who would be more inclined to use a particular type of technology. This fact makes them key elements in establishing contact with surgeons and with hospitals.

Surgeons

Surgeons are the ones who will use our software. It will therefore be important to listen to them and meet their needs as best as we can. This is the reason why a year of tests will be needed in order to adapt our product to their needs.

3.9.3 Channels

Since Guinevere's solution can be considered as a large investment for a surgery department, its price will not be directly exposed online. The company's website will serve more as a business showcase than as a sales channel. The advantages Guinevere delivers to surgery departments will be featured, like the cost reduction, the time optimization and the safer conditions for patients for instance. Then will come partners' video testimonies. This business showcase aims to prove the medical staff that this product would improve their workflow, before revealing the price. To access this information, powerful sales operations will be required. Guinevere's sales representatives will be properly trained, first by simulating sales operations with partner hospitals, and then they will prospect for new hospitals. Face-to-face selling will be paramount, and online resources will be used to support this. In conclusion, the only channel used by Guinevere will be face-to-face sales through the founders in the first instance. Then, when the company is financially stable, it will hire a sales representative specialized in the medical sector.

3.9.4 Customer Relationship

The relationship with the first hospitals will play an important role for Guinevere's future development. As presented earlier, all existing companies have partnerships with hospitals. This is how they can gain other hospitals' trust and increase their solution's sales. During UStart's webinar dedicated to medical entrepreneurship, Louis-Philippe Broze, founder of Spentys, illustrated how he perceived the relationship between his startup and hospitals.

As the latter are currently facing a pandemic, many new needs appeared. While Spentys is normally selling 3D printed orthopedics, they exceptionally pivoted to print connector tubes and face shields to fight the coronavirus' spread. They sell those at the producing cost and do not take any benefit from it. Currently, the entire Spentys team is fully dedicated in producing those equipment. Thanks to this dedication, Spentys is strengthening the relationship with its clients and it may lead to stronger business collaborations in the future (Broze & Henry, 2020).

A hand in hand collaboration allows to better understand the customer's need. Spentys was able to quickly offer the products needed to hospitals because they are constantly in contact with them. Developing such a relationship will help Guinevere to constantly design and improve its product following its user's needs.

To conclude, the customer relationship management with the hospitals must be really well coordinated. Both surgeons and radiologists are needed in Guinevere's sales process and a weaker relationship with one of those could lead to the failure of the contract, which would result in a financial loss. There will be important necessary investments to ensure successful relationships with customers, such as a powerful Customer Relationship Management (CRM) software integrated in our ERP. Zendesk seems to be a great tool as it is well designed for the health-tech industry, it allows a well-suited pricing for startups and it is scalable thanks to its cloud-based platform (Zendesk, 2020).

3.9.5 Revenue Streams

Business models have considerably evolved through the years and many new models have appeared with the Internet revolution. This new sales channel allowed a number of new sales possibilities and the scaling of businesses. So much that it is not always easy to choose one among this abundance. Furthermore, despite this abundance, business models are also becoming unique. This is called the business model innovation which refers to the creation of a new business model following a certain methodology (Lindgren & Jørgensen, 2012).

In this section, two different business models will be further analyzed: the subscription-based business model and the direct sales business model. It should be noted that these two models are the ones that the team was hesitant to adopt. In addition, the type of software license will also be discussed.

Business Model Selected

Subscription-Based Business Model

As the market for operating rooms has its limits, at least in Belgium, the number of new

clients will progressively decrease over time as Guinevere reaches a certain percentage of market share. Therefore, the subscription business model seems to be a relevant choice as it could create a constant source of revenue from this geographical client base. This model has also the advantage to predict future revenues based on the number of clients and the price of the subscription fees. To justify these monthly payments, features will need to be updated on a regular basis and a constant support should be available. The hardest task will be to convince potential customers to take the plunge to buy Guinevere's solution. Indeed, the three most significant factors of the decision making in a subscription-based model are the convenience, the importance of the need, and the usage frequency of the service (Wang, Zhang, Ye, & Nguyen, 2005). Those aspects will need to be sufficiently advertised by Guinevere's Sales Development Representative when they will be in contact with potential customers.

Type of Software Licensing

The software developed by Guinevere will need to be licensed as proprietary, open-source or hybrid in terms of rights of access to the source code. Each type presents advantages and disadvantages. The first risk that comes to mind is the loss of control of the company's code. This would facilitate the entrance of new competitors as those could use Guinevere's resources to build their own company. However, existing companies can also access it and adapt their solution (Muselli, 2008). This represents a threat to the viability of Guinevere. On the other hand, the Open-source strength is related to its community and its transparency (Open Source Initiative, 2020). The advantage to go open-source will be more in the image Guinevere wants to reflect rather than the actual benefits of open-source, which are the collaboration of a developer's community to improve the code of the company. Open-sources projects like Linux have indeed been developed through the community of open-source developers. Nonetheless, among the open-source projects that are online, very few have received this kind of engagement.

Therefore, relying exclusively on the image that open source could give to Guinevere does not seem relevant, which is a decision was made to opt for a proprietary license.

3.9.6 Key Resources

In this subsection, the resources at Guinevere's disposal and the needed resources for its growth are discussed. The intellectual, material and human resources will be explained below while the financial ones will be developed in the financial plan.

- Intellectual resources are at the basis of this project. The Professors Vanderdonckt and Roselli, as well as their research team, have developed a multivectorial algorithm in the field of gesture recognition that has a higher recognition rate than the existing

ones. This confers a real competitive advantage to the Guinevere team and especially in the surgical environment, where precision is needed and little details can impact the success of an operation.

- The human resources are composed of a team of rich and diverse profiles. This plays also in Guinevere's favor as people working in communication, IT, economics and business are behind the project. Furthermore, Guinevere can compensate the lack of internal medical profiles, thanks to its UCLouvain University origins, which has a medical faculty as well as different hospitals.
- UCLouvain and LTTO resources, it is very difficult to determine the concrete benefits they will bring us, as it will depend on the patent application and the state of the spin-off. Nevertheless, a workspace and access to other resources can likely be considered.
- The material resources are mainly four Leap Motions that will be purchased in the first year for the test. Also, other material resources will be necessary in order to run the business properly such as personal computers, professional mobile phones, offices, the CRM, among others. This will be discussed in more details in the financial plan presented in chapter 7.

3.9.7 Key Partners

To ensure the success of the Guinevere project, the relationship with the partners will play an important role. A list and a brief description of each of them is written below.

- **UCLouvain** will be needed as explained in the Key Resources subsection as this will give to Guinevere a first access to a hospital that could potentially become a customer. Guinevere will have to maintain a deep relationship with this actor as it is crucial to the success of the project.
- Even though **Hospitals** are considered as customers, the important relationship with them also makes them partners.
- Guinevere's software will first be integrated into the existing DICOM viewer (Digital Imaging and Communications in Medicine (NEMA, 2017): the international standard to transmit, store, retrieve, print, process, and display medical imaging information.) Then, during the test year, we will study the possibility of creating our own DICOM Viewer with all the required functionalities. In addition, since **Carestream DICOM** is the one used by the UCLouvain hospitals, a collaborative relationship will be considered.
- **Sensor suppliers** are various on the market but the ones that specifically respond

to Guinevere's needs are fewer. The **Leap Motion** is the first choice.

3.9.8 Key Activities

Guinevere's main activities are related to the integration of its software, sensor configuration, medical staff training in using the solution and finally the support provided to them.

Concerning the integration, it will make the link between Guinevere's gesture recognition module and the customers' medical software, namely the DICOM viewer. The first integration with a specific software will always require a certain amount of time as all the connections need to be coded. Therefore, customers' prospecting needs to be done strategically. As said above in the previous section 3.9.7, the UCLouvain and its hospitals are using the medical software Carestream. Then, for the second client of Guinevere, the ones using Carestream will be targeted first as the development work will already be done and will be implemented much faster.

Afterwards, the setting of the sensor and training of the medical staff will be done by a commercial team and will be necessary for each customer. Finally, the support will be consistent. Focusing first on a simple and single medical software will give Guinevere's team some expertise and the time to grow progressively.

3.9.9 Cost Structure

The cost figures will be fully outlined in the financial section 7.2. The costs are divided into variable costs which are closely related to the activity and particularly the purchase of the Leap Motions, fixed costs which are related to the CRM subscription, salaries, insurance etc. and investment costs which are related to the patent and the cost of launching the company.

3.9.10 Graphical conclusion of the Business Model Canvas

Key Partners	Key activities	Value proposition	Customer relationship	Customer segments
• UCLouvain and LTTO • Hospitals : - Surgeons - Radiologists - Heads of services - Medical directors • DICOM AND PACS owners • Sensor suppliers	• Software integration • Sensor setting • Medical staff training • Support	• Solve the sterility-related problem in the operating room • Faster and more efficient operation • Cost savings for hospitals	• Direct sales • Competitive advantage	• Hospitals : - Surgeons - Heads of services
	Key Resources		Channels	
	• Research team • Interdisciplinary team • LTTO and UCLouvain resources • Operating resources		• Website • Sales representatives	
Cost structure			Revenue Streams	
• Variable costs: Leap Motion • Fixed costs: CRM, salaries, insurance, etc.. • Investments: Start up cost, patent			• Monthly subscription paid by hospitals for the solution	

Figure 3.10: Business Model Canvas of Guinevere

3.10 Conclusion

The purpose of this chapter was to select the gesture recognition market in which Guinevere would enter. It was also used to analyze the market in its environment and how it would be possible for our company to integrate it.

The writing of this chapter forms the basis of this master thesis in the sense that the overall objective is the creation of a company in the sector defined by this section. The following chapters are therefore all based on it.

Strategic Analysis	
Gesture Interaction Market	- \$34.25 billion in 2022 growing at a CAGR of 24.2% - This technology is well established at the touch-based recognition level and continues to develop at the touchless level.
Potential Markets	The operating room market was chosen : - Nearly 234.2 million operations each year. - More complex technologies are already emerging. - Reducing the risk of infection and time saving.
PESTEL	Most important factors of the environment: - Belgian health budget growth is decreasing. - The MedTech sector is booming in Belgium. - Conservatism in the Medical sector - The high figures for hospital-acquired infections
University Spin-off	Advantages: 1) Label from University 2) UCLouvain has two clinics 3) Sopartec (investment fund) Disadvantages: 1) transfer of the intellectual property 2) being diluted from the outset.
Porter's five forces	Fairly attractive mostly due to the small number of competitors and the different barriers to entry.
Bowman's Strategic Clock	Differentiation strategy which implies a high perceived value to the customers
SWOT	- S: Belgian market, complementary team and, technological advantage. - W: Lack of experience, lack of financial resources and, lack of expertise. - O: Booming sector in Belgium and market readiness. - T: Belgian healthcare budget, Covid-19, and big corporations potential entry
TOWS	- The partnership with UCLouvain is key for our company. - File for a patent - Small structure which allows us to be much more flexible
Business Model Canvas	Monthly subscription-based business model and proprietary licensing software.

CHAPTER

4

PRODUCT OUTLINE

In this chapter, the product as well as the technical aspects will be presented. To begin with, a literature review will be established to see what has already been done. Since the product can be divided into two parts, the gesture recognition and the DICOM viewer parts, the technical aspects of each part will be analyzed and discussed. Finally, the limitations of the product as well as its improvements will be presented.

4.1 Terminology

- Digital Imaging and Communications in Medicine (DICOM): the international standard to transmit, store, retrieve, print, process, and display medical imaging information (NEMA, 2017).
- Picture Archiving and Communication System (PACS): system for managing and saving medical images

4.2 Literature Review

4.2.1 Framework

This section will briefly describe the best-known frameworks with their pros and cons. Known as Gesture Middleware Systems, this category of software aims at easily integrating gestural interaction in any application. A more exhaustive list can be found in Magrofuoco and Vanderdonckt (2019)’s work.

IGesture (Signer, Kurmann, & Norrie, 2007) is an open source Java-based gesture recognition framework allowing to capture and manage 2D stroke gestures with a pen or mouse, to recognize gesture with predefined or custom recognizers and to benchmark recognizers. It has many abstractions allowing a high degree of modularity but is limited to the application being in Java.

ARAMIS (Carrino, Mugellini, Khaled, & Ingold, 2011) is a multimodal framework allowing to manage and merge information from heterogeneous, distributed sensors. The emphasis is mainly on merging the data and no details are present on the possibility of using another recognizer than the present one.

Kind-Dama is an open source middleware that enables gesture recognition through a REST API. It also allows the addition of new sensors and the management of gestures. This framework allows to have several sensors and has several gesture recognizers. The presence of a REST API allows to be cross-platform. Unfortunately, there is no module allowing easy integration into an application (Milazzo, Gentile, Gentile, & Sorce, 2018).

Euphoria is a scalable, event-driven architecture for designing interactions across heterogeneous devices in smart environments. This architecture has a very high modularity and allows to easily add a new sensor but unfortunately the gesture recognition is not integrated in it (Schipor, Vatavu, & Vanderdonckt, 2019).

Compared to the literature, the empirical approach used for a real non-trivial application case allows to show all the power of a framework. The **high degree of modularity** linked to the **abstractions of the different parts** as well as a **unified representation** of the gestures allows an **unequalled compatibility**.

4.2.2 3D Hand Gesture Recognition

3D hand gesture recognition is a complex multi-step process, each step being a research topic in itself. The process can be divided into three steps : hand detection, hand tracking and recognition of the gesture being performed. As the first two phases are integrated in the sensor we plan to use (the Leap Motion), only the third phase will be discussed here (Rautaray & Agrawal, 2015).

There are many techniques for classifying gestures. The main techniques between 2016 and 2018 can be found from Yasen and Jusoh (2019)’s systematic literature review: Artificial Neural Networks (ANN) - convolutional neural network, recurrent neural network, etc.; K-nearest neighbor (KNN); Decision tree classifier; Support vector machine (SVM); Hidden Markov Model (HMM); Dynamic time warping (DTW); Naive Bayes classifier; Linear discriminant analysis (LDA); Principal component analysis.

Two problems for artificial intelligence algorithms have been identified in the literature: **overfitting** in the data sets and **lack/difficulty of live training** (Yasen & Jusoh, 2019). Overfitting is the act of training a model too close to the starting data and then preventing the recognition of new data. Live training is the ability to add new data without having to re-train the whole model. To avoid these problems, only template matching techniques will be used in the prototype and thus detailed.

\$3 is an adaptation of Wobbrock, Wilson, and Li (2007) to recognise 3D gestures. The recognizer was presented as adapted to prototyping environment. It uses the acceleration data of a single point, for example provided by the accelerometer of a Nintendo Wii Controller. Because of its simplicity, it can be easily adapted to all kinds of sensors, as long as acceleration data are provided. It does not need a lot of training data. It can distinguish a limited set of gestures (10 to 15), more gestures result in higher computational overhead and lower accuracy (Kratz & Rohs, 2010).

Protractor 3D has the particularity of being rotation invariant. It finds the rotation that minimises the sum of square errors (euclidean distance) between a gesture and a template. It is possible to set a max threshold for the rotation, above which the gesture is considered as different from the template. It has the same advantages as \$3, but is more accurate (Kratz & Rohs, 2011).

3 Cent Recognizer is also an adaptation of Wobbrock et al. (2007). It’s the same idea of \$3 and Protractor 3D, comparing sampled trajectories, but with different and simpler processing options. This translates into higher performance and accuracy of the recogniser. It has the particularity of scaling with respect to the length of the gesture (normalised length of 1) instead of scaling a fixed size bounding box (which can distort the gesture) (Caputo, Prebianca, Carcangiu, Spano, & Giachetti, 2017).

Jackknife is a general recognizer designed to recognize gestures both in 2D and 3D. The gestures are represented as a set of unit-length direction vectors. A gesture is compared with all templates, and matches with the template that has the lowest distance, computed using Dynamic Time Warping (DTW).

The three first algorithms require the pre-segmentation of gestures (indirect approach). Jackknife used a sliding-window approach to segment the gesture.

The taxonomy of Cheng et al. (2015) in the figure 4.1 can be used to classify the different gesture recognition techniques. This taxonomy is divided into three categories:

- Static gesture recognizer: recognizer detecting static gestures.
- Trajectory gesture recognizer: recognizer detecting the sequential data (temporal for example) of one point of the gesture.
- Continuous gesture recognizer: recognizer detecting general hand trajectory.

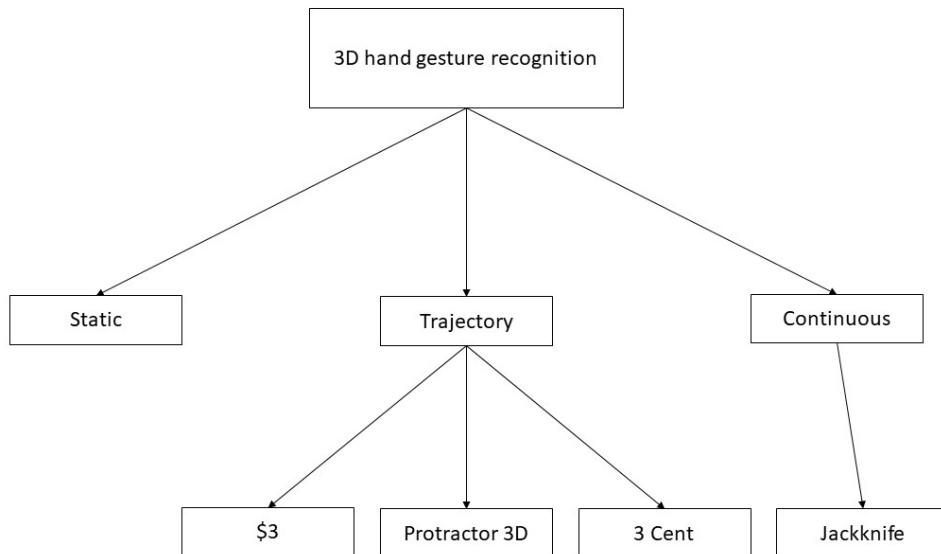


Figure 4.1: Gesture recognition taxonomy inspired from (Cheng et al., 2015).

4.2.3 Medical Domain

The fact that surgeons cannot manipulate medical images because of sterility issues has been brought out for a while in the scientific literature. Indeed, already in 2003, the Federal Polytechnic school of Lausanne had developed a mouse based on first technologies of gesture recognition (Grätzel, Fong, Grange, & Baur, 2004). Later, sensors that allowed more reliability in gesture recognition through laser and infrared cameras such as the Kinect in 2010 or the Leap Motion in 2012 allowed the possibility of a deeper research.

The integration of gesture in medical software has been widely discussed, the most recent review of the literature, from Mewes, Hensen, Wacker, and Hansen (2017), shows this abundance. Several works are very relevant to the application case studied. Wipfli, Dubois-Ferriere, Budry, Hoffmeyer, and Lovis (2016b) verified that gesture interaction was really more efficient than using a third person when the surgeon could not have access to a mouse (the mouse being the fastest way otherwise). Madapana et al. (2019) conducted

an elicitation study to find the essential PACS manipulations and their corresponding gestures and O'Hara et al. (2014) highlight some practical points to pay attention to.

The creation of a product was also discussed. Some applications have been created: (Jacob & Wachs, 2014), (Massaroni et al., 2018). Others wanted to extend existing software, like Osirix (Ebert, Hatch, Ampanozi, Thali, & Ross, 2012), and MITO (Gallo, Placitelli, & Ciampi, 2011). All of these products were created for research purposes and none appear to be commercially available.

Different sensors were also used: Microsoft Kinect (Gallo et al., 2011), Leap Motion (Bizzotto et al., 2014), MYO Armband (Sánchez-Margallo, Sánchez-Margallo, Moyano-Cuevas, Pérez, & Maestre, 2017), and more recently Microsoft HoloLens (Kasprzak, Pawlowski, Peruga, Kaminski, & Lipiec, 2020).

Compared to the literature, the approach angle of a **framework module** and **decoupled from the application case** allows to easily change and improve gesture recognition without modifying the DICOM viewer or easily change the DICOM viewer. Moreover, the gestures chosen result from an **elicitation study**.

4.3 Analysis and Specification

4.3.1 Framework

The goal of the framework is to be able to have the gesture recognition part flexible enough to be used in other cases of application in order to support gestural interactions happening between end-users and a computer system.

The list of functionalities has been constructed on the basis of computer programs found in the literature as well as the experience gained during the development of the prototype. The features will be explain in the form of user stories for the functional requirements and technical stories for the technical requirements (Cohn, 2004).

Functional requirements

- As a programmer, I want to easily use a sensor in my application in order to retrieve the user's data.
- As a programmer, I want to perform an action in response to a gesture in order to interact with the user.
- As a programmer, I want to choose the recognizer I use in order to take the most adapted to my application.
- As a programmer, I want to add my own gesture recognizer in order to use it in my application.

Technical requirements

- The system must be usable in different programming language in order not to be limited to one programming language and to be suitable for the widest possible audience.

4.3.2 Surgery

The goal of the application is to enable surgeons to manipulate medical images without contact. The full list of functionalities has been constructed on the basis of computer programs found in the literature as well as existing DICOM viewers (OHIF Viewer and Osirix mainly). The features will be explain explained using the same method applied to the framework part. Only a subset of the functionalities has been implemented for the prototype, as justified in the section 4.5.1.

Functional requirements

- As a surgeon, I want to see MRI or CT images in order to help me during my surgery.
- As a surgeon, I want to easily navigate in an image in order to retrieve quickly the information needed during my surgery. I want to:
 - Zoom in/out in an image
 - Rotate an image
 - Translate an image
- As a surgeon, I want to switch between series of images and studies in order to get the information present in different images.
- As a surgeon, I want to have a complete set of ROI (Region-Of-Interests) tools that are available to measure angles, surfaces, distances, densities, SUV, Cobb angle, volumes in order to have accurate information.
- As a surgeon, I want to use image fusion (explanations under picture 4.2) in order to have a better spatial visualisation of the problem.

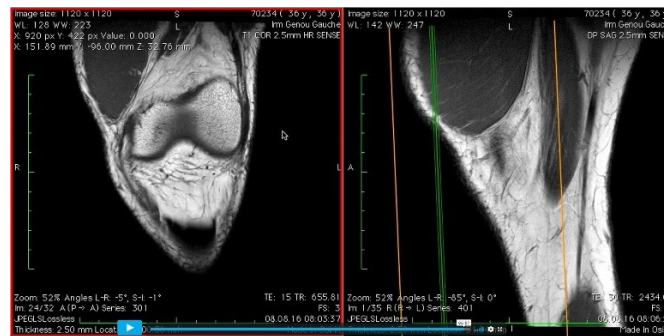


Figure 4.2: The picture on the right is a lateral MRI of a knee. The green line represents a cross section and is shown in the image on the left. The green line can be moved and the image on the left is changed according to.

- As a surgeon, I want to be sure that the image does not move when I operate, in order to avoid clinical complications or wasting time removing it
- As a surgeon, I want to adjust various image parameters in order to better see the image. I want to:
 - Change the contrast of an image
 - Change the density functions of an image(to reveal different features such as bone, tissue or blood vessels)
 - Change the opacity of an image

Technical requirements

- The standard ISO 12052 (for the medical image) must be supported in order to be compatible with PACS systems on the market (NEMA, 2017).

4.4 Guinevere Software Architecture

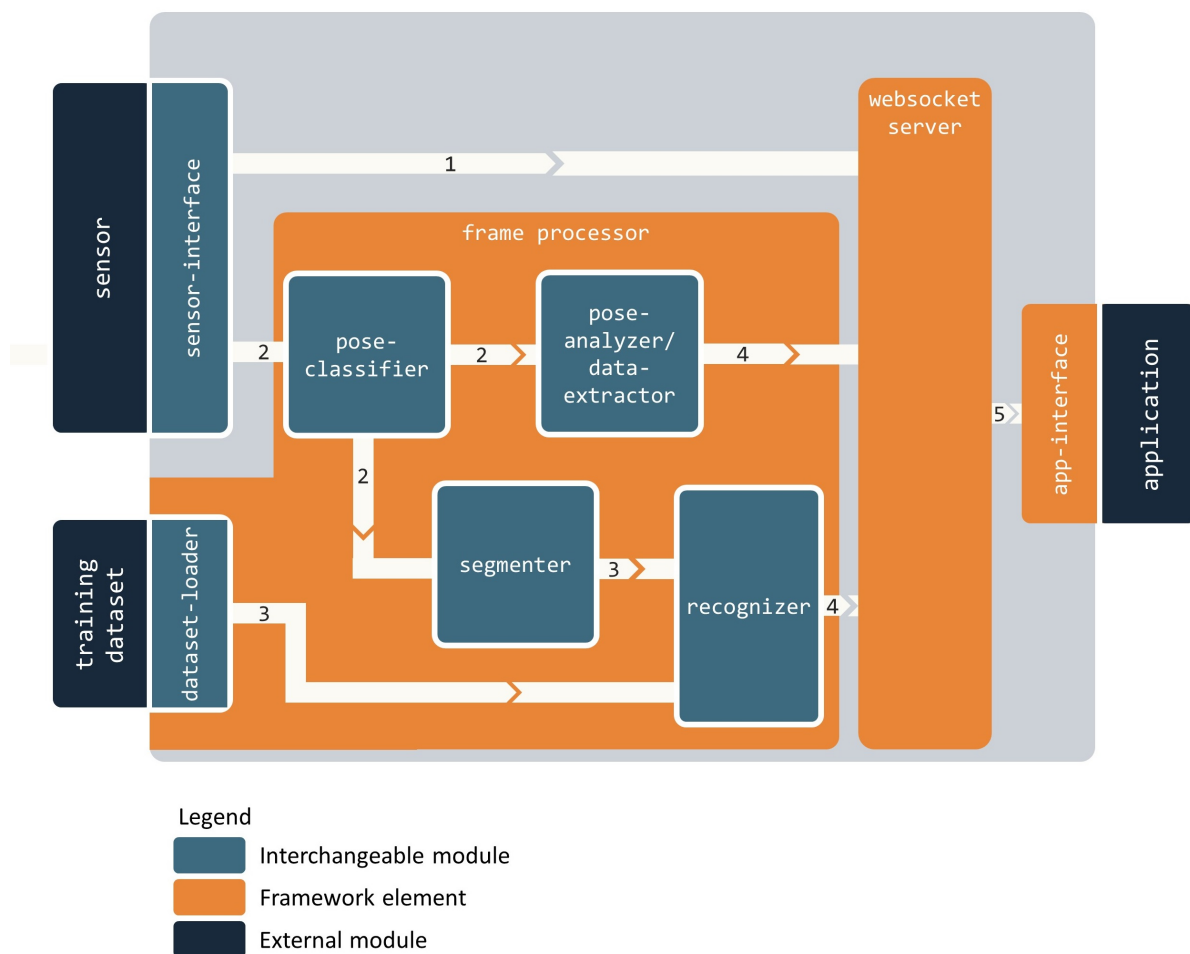


Figure 4.3: Framework architecture

The framework, shown in figure 4.3, is built as modular as possible in order to be able to change sensor, database, recognition algorithms. It is sufficient to implement the corresponding interface and to specify in the configuration file the chosen module. The workflow is as follows. The (gesture) recognizer is trained with the data provided by the dataset-loader. Then, the sensor sends frame by frame in a pose-classifier implemented by Sluÿters (2020). If a pose (a static gesture) is recognized, it is sent directly to the application. Otherwise the data is either sent directly to the gesture recognizer or to a segmenter if the recognizer does not manage this step. Once a gesture is recognized, a message is sent to the application and the action corresponding to the detected gesture is performed.

The exchanges between the different blocks are standardized and are represented by numbers in the figure. Here is the meaning of each number:

1. A frame containing all the information coming out of the Leap Motion
2. A data structure representing a frame. See 4.4.1 for more details.
3. A data structure representing a gesture. See 4.4.1 for more details.
4. A dictionary containing the name of the recognized gesture and the time taken to recognize it.
5. A dictionary containing the name of the recognized gesture (if a gesture has been recognized) and a frame following the format number 1.

The framework is completely detached from the application case. On the application side, the node module *app-interface* need to be added and the class *GestureHandler* need to be instantiated to make the link with the gesture recognizer. For an action to be performed when a gesture is recognized, it is enough to call a method specifying the gesture and the function must be called in response to a gesture so that the function is automatically called as soon as the gesture is recognized.

Currently, the framework supports one input modality and one output modality, as shown in figure 4.4 according to the architecture of Cronel, Dumas, Palanque, and Canny (2018).

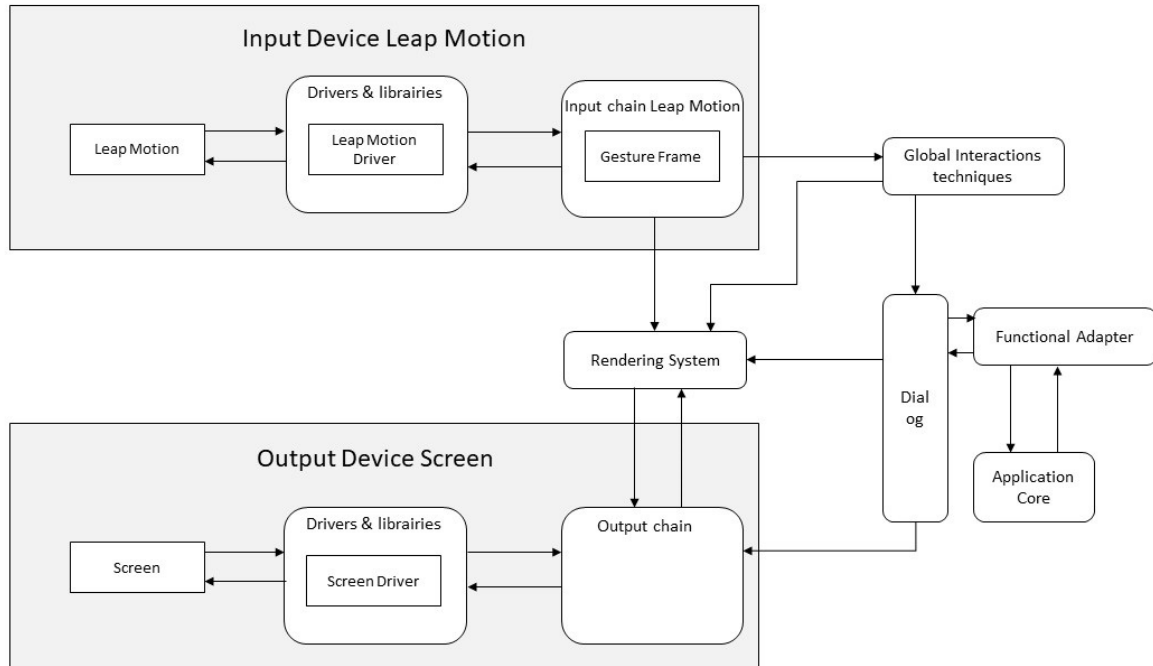


Figure 4.4: Framework architecture

4.4.1 Technological Choices

Programming language

Javascript was chosen as the language for several reasons. First, working in collaboration with Arthur Sluÿters, the decision was made to use a common language and the application he was working on was in Javascript. Second, the recognition algorithms were already in Javascript. Moreover, Javascript is a cross-platform language and corresponds well to the desired requirements. In addition, TCP connections have been chosen to communicate between the framework and the application to enable cross-language compatibility.

Unified Format

It was decided to save the data set in a standardized format described below. The format is designed to support any type of data set gesture (2D/3D, unistroke/multistroke, unitouch/multitouch) and may later allow to standardize other data sets. It was inspired by the format given by Nathan Magrofuoco, extended and improved in collaboration with Arthur Sluÿters and Dilara Gouveia.

File tree structure

It was decided that each file will contain a repetition of a user's gesture. There are several ways to arrange the files. The different possibilities are:

- One folder per user and directly all the corresponding files in it
- One folder per user and one folder per gesture
- One folder per gesture and all files of all users directly in it
- One folder per gesture and one folder per user

The choice made was that of **one folder per gesture and one folder per user**. The notion of gesture is more important than the notion of user in a real case of application. It is more useful to be able to easily extract gestures if needed than a user.

File names

It was decided to take a naming convention for the files. Following the advice of (Cowles, 2020; PODE, 2020; Stanford University, 2020), the following points were taken into account in the choice of convention:

- A sequential numbering system will be used to number the users and one to number the repetitions of the same gesture. Leading zeros will be used for clarity and to make sure files sort in sequential order. Since the user and repeat number will not exceed 100, two digits will be used.
- Special characters `~ ! @ # $ % & * ( ) ' ; < > ? , [ ] { } ' " and |` will be avoided
- Spaces will not be used
- The elements in a file name will be ordered in the most appropriate way to retrieve the record

The chosen convention: `compound_gesture_name-additional_information-id`

The different information is separated by a dash. If a piece of information contains several words, these are separated by an underscore. The different informations are

- `compound_gesture_name`: The name of the gesture. If the name of the gesture is composed (swipe left for example), an underscore is used to separate the words as explained above (`swipe_left`).
- `additional_information`: This field is optional and is left open for interpretation if further information is required. It makes it possible to include the notion of variation of gesture for example for the acquired data set (swipe left with open hand, with only the index pointing, etc).
- `id`: The id of the repetition of the gesture for a user.

Gesture representation in file

It was chosen to save the gesture samples in json files due to the great portability and notoriety of this format. Each file contains the information below:

```
1 "name": string - e.g., "swipe up"
```



```

2 "subject": integer
3 "modality": object - object representing the modality used
4 "device": object - object representing the device
5 "date": string - following the ISO 8601 syntax (YYYY-MM-DD),
  e.g., "2020-05-08"
6 "paths": array of Path objects
7   "label": string - e.g., "rightHandPosition"
8   "strokes": array of Stroke objects
9     "id": integer
10    "points": array of Point objects
11      "x": float
12      "y": float
13      "z": float
14      "t": integer - milliseconds since the Epoch

```

Gesture representation in framework

In order to be able to support any dataset and any gesture recognizer, the framework has an abstraction representing a gesture that can be seen as the UML diagram 4.5.

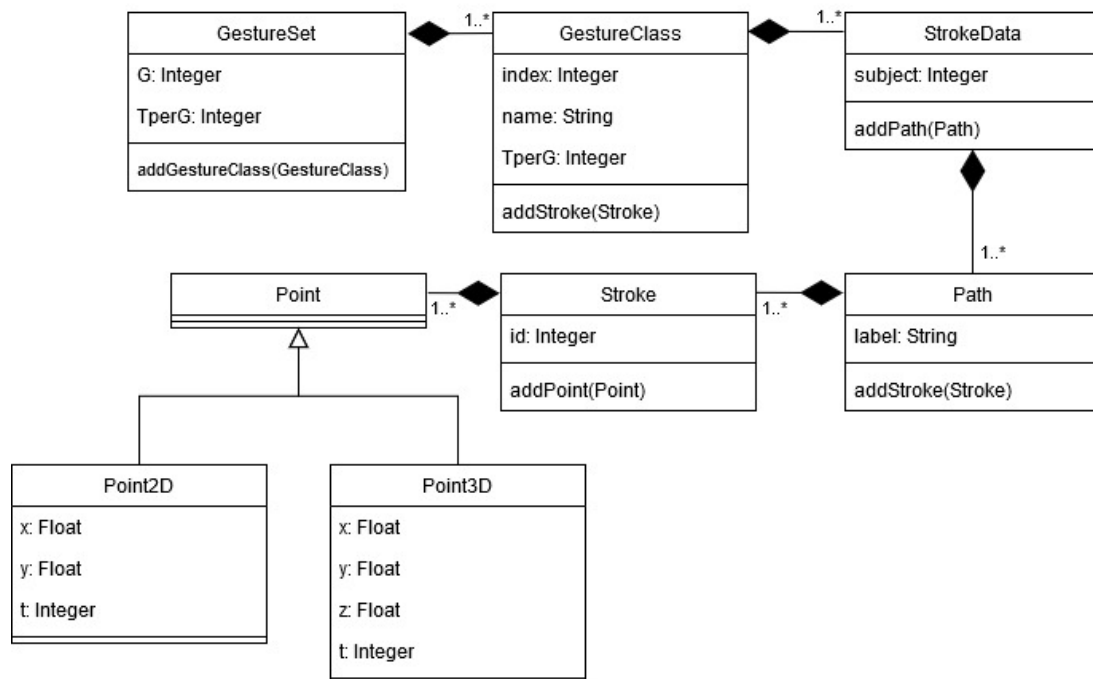


Figure 4.5: Gesture representation UML V2.0

At the moment two types of points are accepted: 2D and 3D points. This is related to the two types of devices that have been used so far and that can be placed in Buxton

(2009)’s taxonomy as shown in bold in figure 4.6. But it is very easy to support a new type of data. For example, if it was necessary to add quaternions supported by the LogBar Ring, it would be enough to add a `QuaternionsPoint` class that extends *Point* and contains the attributes (w, x, y, z) (Logbar, 2014).

		Number of dimensions							
		1		2			3		
Property sensed	Position	Rotary Pot	Sliding Pot	Tablet	Tablet & stylus	Light Pen	Floating Joystick	Leap Motion	Mechanical
				Touch Tablet					Sensing
	Motion	Continuous Rotary Pot	Treadmill	Mouse			Trackball		Mechanical
									Sensing
	Pressure	Torque Sensor					Isometric Joystick		Sensing

Figure 4.6: Buxton (2009)’s input taxonomy

Frame exchange format

To represent a frame, the following structure has been chosen:

```

1 "timestamp": integer - milliseconds since the Epoch
2 "hasLeftHand": boolean
3 "hasRightHand": boolean
4 "articulations": array of Articulation objects
5   "label": string - e.g., "rightHandPosition"
6   "points": array of Point objects
7     "x": float
8     "y": float
9     "z": float
10  "t": integer - milliseconds since the Epoch

```

Configuration files

It was decided to create a js configuration file for the advantage that it can be programmed and thus the different recognizers can be initialized in it. The configuration file allows to choose the dataset as well as the recognizer without having to change the rest of the code. Such a level of modularity can be classified as "Configurable" according to McKinley et al. (2004)’s classification (cf figure 4.7).

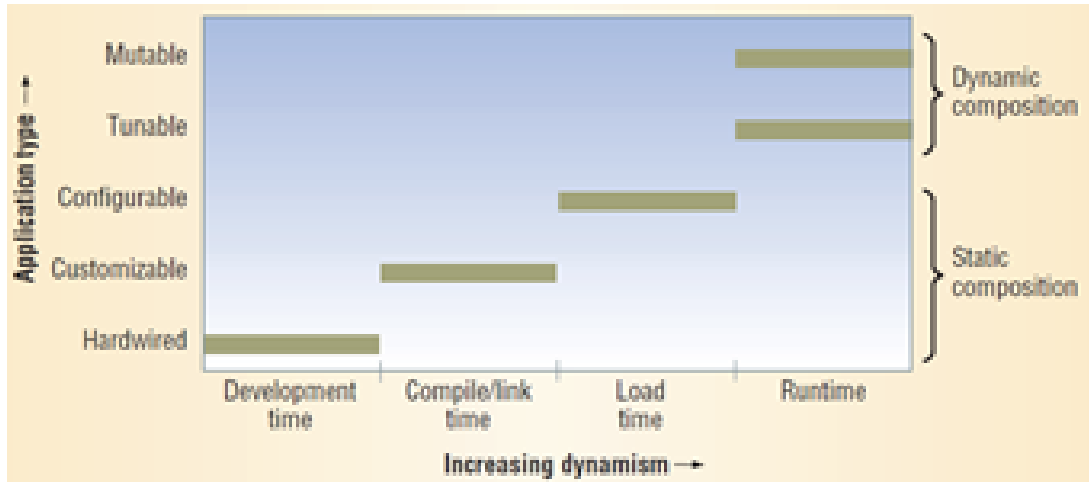


Figure 4.7: Classification of McKinley et al. (2004)

Gesture Segmentation

In collaboration with Sluÿters (2020), 3 segmenters have been implemented:

Left-Hand Segmenter is a segmenter using the presence of the left hand as a delimiter. Although having the particularity of being very simple to implement, it does not allow two-handed gestures, the left hand being used to delimit the beginning and end of the gestures.

Zoning Segmenter is a segmenter starting/stopping a gesture as soon as the presence/absence of a hand in a delimited area is detected.

Sliding Window Segmenter is a segmenter using a fixed-size buffer called the window. Each time a new frame is received, it is pushed in the window, while the oldest frame is removed. Every fixed number of frames, the buffered gesture data is sent to the recognizer.

Because the *Sliding Window Segmenter* approach does not limit the movements of users and does not require them to use their left hand, this approach might seem like the best. However, it only works well if the recognizer can differentiate between intended gestures and movement with no specific meaning. Furthermore, it causes more strain on the CPU as the recognizer always runs at a fixed interval, regardless of whether the user has performed a gesture. Because of the fixed window size, it also poses a constraint on the duration of the gestures.

4.5 Prototype

The main purpose of the prototype is to show the possibility of performing the necessary operations in an operating environment. As the image 4.8 shows, the prototype consists only of an image that can be manipulated through gesture. In order to allow compatibility

with the standard ISO 12052 (NEMA, 2017), the external open source library (under MIT license) cornerstone has been used (Cornerstone, 2020). This allowed to link the prototype to the orthanc open source PACS (Orthanc - DICOM Server, 2020) in order to view its images and not to worry about the management and exchange of images with the rest of the hospital ecosystem. The gesture recognition module is independent and can easily be incorporated into other DICOMs (see 4.3.1 for details). The source code can be found in the appendix A.

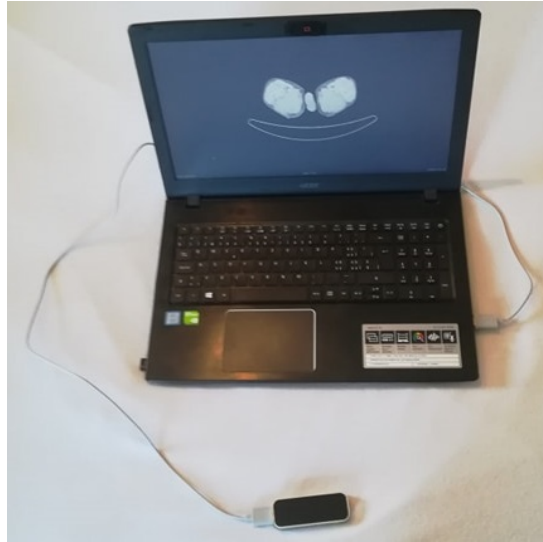


Figure 4.8: First prototype

A Leap Motion sensor is used to acquire gestures (Ultraleap, 2020). The sensor was chosen for its ease of procurement and accuracy (One of the most accurate low-cost hand tracking sensors according to Guzsvinecz, Szucs, and Sik-Lanyi (2019)). The Leap Motion can be used in a hospital environment as Pauchot et al. (2015) tested it with the installation shown in image 4.9. The sensor is placed in a see-through sterile cover. The cover is stretched with a sterile elastic band to allow the sensor to function properly. Due to the size of the device, the Leap Motion can be placed at the surgeons' convenience, for example on a sterile cart near them.



Figure 4.9: Leap Motion setup - from (Pauchot et al., 2015)

4.5.1 Technological Choices

Gesture set

The main problems and points of attention to look for when choosing gestures are highlighted by O’Hara et al. (2014). The biggest problem concerns the high number of possible functionalities for a DICOM (known as expressive richness). O’Hara et al. (2014) summarizes some solutions: use of modes to distinguish gestures; use of composite multi-handed gestures (one and two-handed gestures); use non-dominant hand for selecting particular functions or modes while the dominant hand moves within the XY and Z planes for the continuous adjustment of image parameters. Another important point is the context related to each gesture and thus the number of hands available to perform the gestures. Sometimes surgeons have to manipulate an image while holding various medical instruments.

With these points of attention in mind, the prototype data set can be constituted. Of the 28 actions necessary to make all the possible manipulations coming from Madapana et al. (2019), 14 were chosen taking into account the remarks of Strickland, Tremaine, Brigley, and Law (2013): The features that surgeons find most useful during an operation are the ability to animate CT and MRI scans and to switch between different series within a study. Features such as windowing, zooming, rotating, highlighting points of interest and annotating were considered less useful.

The data set was acquired by 4 different persons with 4 repetitions per gesture. The complete data set built in partnership with Sluÿters (2020) can be found in the appendix B. The list of actions concerning the medical field as well as the corresponding gesture can be found in table 4.1. The corresponding gesture for each action was chosen on the basis of (Sluÿters, 2020)’s elicitation study (shortened S) or on the basis of Madapana et al. (2019)’s elicitation study (shortened M). It is important to underline that often the gestures of both studies have the same characteristics (defined as descriptor by Madapana et al. (2019)). The gestures have also been classified according to their form according to the taxonomy describe in section 2.3. The following abbreviations are used: O = stroke; SP = static pose; DP = dynamic pose; SPM = static pose with motion; DPM = dynamic pose with motion.

Category	Action	Gesture	Form	Gesture origin
Studies navigation	Next study	Swipe left	O	S
	Previous study	Swipe right	O	S
Image animation	Forward	Swipe up	O	A
	Backward	Swipe down	O	A
Image manipulation	90° rotation clockwise	Turn invisible button clockwise	DP	S
	90° rotation anti-clockwise	Turn invisible button anti-clockwise	DP	S
	Zoom in	Pinch out w/ index and thumb	DP	S
	Zoom out	Pinch in w/ index and thumb	DP	S
	Increase contrast	Left hand C shape	SP + O	M
		Right hand swipe up		
	Decrease contrast	Left hand C shape	SP + O	M
		Right hand swipe down		
	Pan up	Open hand in up direction	SPM	M
	Pan down	Open hand in down direction	SPM	M
	Pan left	Open hand in left direction	SPM	M
	Pan right	Open hand in right direction	SPM	M

Table 4.1: Gesture set

A particularity added to the data set is the notion of variation for a gesture. A gesture can be assimilated to several executions:

- Swipe left gesture
 - with open hand
 - with only the index pointing
- Swipe right gesture
 - with open hand
 - with only the index pointing
 - with open hand, palm reversed
- Swipe up gesture
 - with open hand, palm up
 - with open hand, palm down
 - with only the index pointing
- Swipe down gesture
 - with open hand
 - with only the index pointing

Gesture Recognizer and Testing

To test a new data set/recognizer, everything occurs in *benchmark.js*. Since data sets and recognizers have a common interface through exchanges in a common format, just specify which data sets and recognizers will be used in the configuration file and all data

set/recognizer combinations are tested.

For the moment, the method was the same as the User-Independent part of Magrofuoco, Vanderdonckt, and Roselli (2020): The evaluation algorithm randomly chose 1 to X samples per gesture class to train the recognizers, then it chose one other sample per gesture class for testing. The whole process is done 100 times.

The two most promising algorithms from the literature have been tested: ThreeCent and Jackknife. Three new algorithms adapted from their 2D versions were also tested:

- P3DollarPlus: the 3D adaptation of P\$++ recognizer (Vatavu, 2017)
- Q3DollarRecognizer: the 3D adaptation of Q\$ recognizer (Vatavu, Anthony, & Wobbrock, 2018)
- Dollar3D: a "dollar" approach made by Nathan Magrofuoco, i.e. by applying resampling, scaling and translation to 3D points, then using the 3-dimensional Euclidean distance to calculate the dissimilarity between these points. A flexible matching was chosen because it takes into account the joints one by one, while giving the necessary flexibility to the fact that gestures are not always produced at the same timing.

The code of all the recognizers can be found in Appendix A.2.

The results for our datasets can be seen in Table 4.2. Results for other datasets can be found in the appendix C. In view of the results, it was decided to use the Dollar3D algorithm for the prototype. The confusion matrix obtained with Dollar3D is given in Figure 4.10. Since the tests were run 100 times, the diagonal directly gives the recognition rate by class. The standard deviation of recognition per class is 11.41. It can be seen that the gestures most often confused are the close ones, such as swipe right/left, pinch in/out or open hand left/right.

Gesture reconizer	Recognition accuracy (%)	Time (ms)
Dollar3D	85,82	3,31
Jackknife	80,76	1,15
ThreeCent	68,41	1,02
P3DollarPlus	54,65	0,14
Q3DollarRecognizer	49,06	1,00

Table 4.2: Gesture recognizer results. Made with a Intel Core i7-7500U CPU @ 2.70GHz 2.90 - 12GB RAM

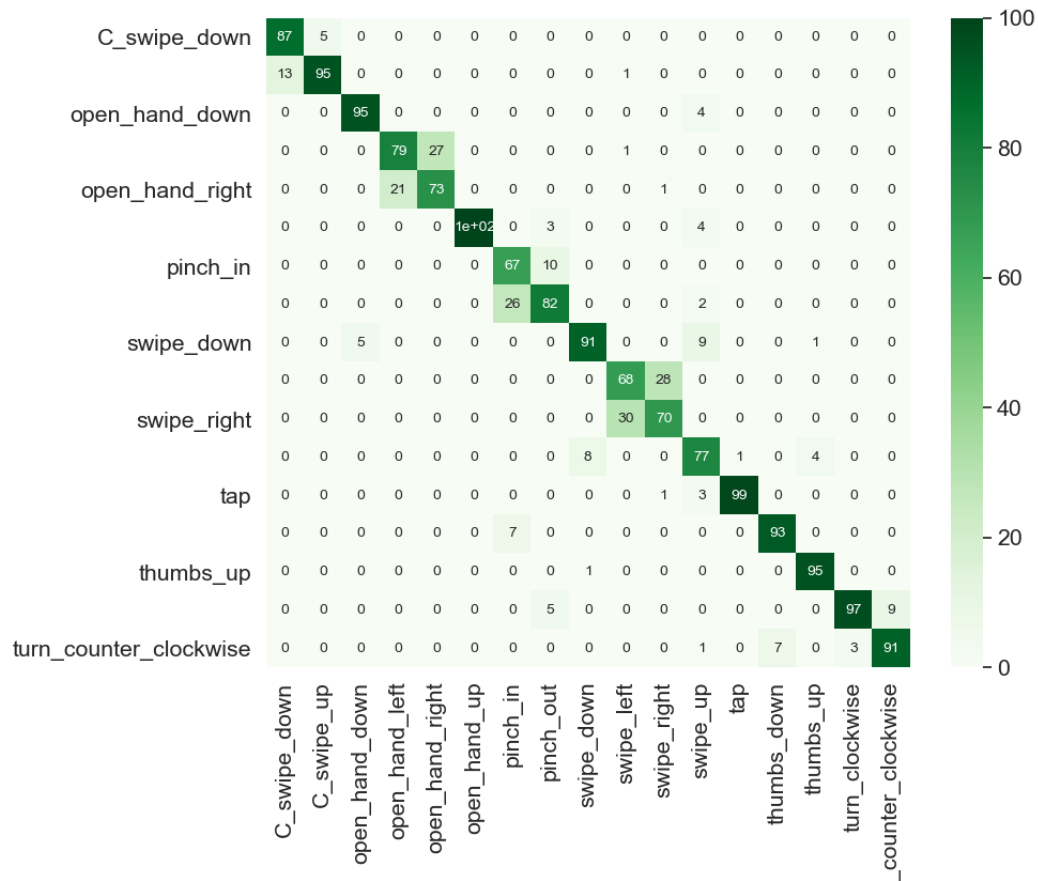


Figure 4.10: Confusion matrix with Dollar3D

4.5.2 Gesture representation

Based on the analysis conducted in Chapter 2, regarding graphic elements needed to represent gestures efficiently, the following representations were created.

This representation, created for the first gesture presented in Table 4.1, is using a first-person perspective, physical objects to create context, hands depiction as well as colors, text and a 1-sided arrow.

The other gesture representations, created for the thirteen remaining gestures from Table 4.1, can be found in the appendix D.

Go to next study

Swipe left

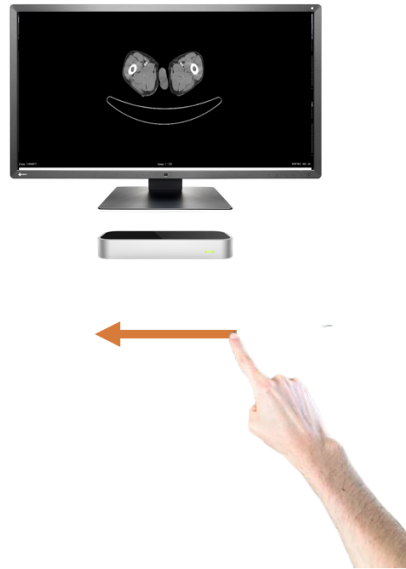


Figure 4.11: Swipe Left

4.6 Future Work

The prototype is promising but many improvements can still be made. Although the theoretical recognition rate is 85%, problems related to segmentation decrease this rate in real conditions. It will therefore be important to invest in more sophisticated segmentation techniques such as machine learning techniques.

It was noted that the acquisition of a data set was a long and tedious task. It could be interesting to create a formal language to express gestures and generate samples thanks to Kinematic Theory (Leiva, Martín-Albo, & Plamondon, 2017).

For the moment, the framework does not have a graphical user interface and does not allow the management of data sets. It might be interesting to be incorporated into Magrofuoco and Vanderdonckt (2019)'s work.

Although the framework returns the values allowing the creation of a confusion matrix, this one is currently created by an external tool made by (Sluÿters, 2020) and the related results (recognition rate by class, standard deviation, etc.) must be calculated separately. It could be interesting to create a visualization tool to process the test results directly.

4.7 Conclusion

This chapter presented the prototype and all the technical aspects surrounding it. The strategic analysis was used in order to define our product. Indeed, the product's characteristics result from the strategic analysis in Chapter 3.

A gesture representation was also given in order for end-users to know how to use Guinevere's product, based on the reasoning developed in chapter 2.

The characteristics of the product will be taken into account in the financial part presented in chapter 7 and will reduce the risks depicted in chapter 8.

Product outline	
Advantages	- Modular - Cross-language and cross-plateform compatible - Unified format
DICOM Viewer	- ISO 12052 compliant - 14 gestures from elicitation study
Recognition rate	Dollar3D algorithm: 85.82%

CHAPTER

5

MARKETING AND COMMUNICATION PLAN

In this chapter, Guinevere's communication plan is exposed. The company's position on the market is explored while the different key messages that will be used are introduced. Furthermore, the definition of the tools, the budget, the target stakeholders and the performance indicators are introduced so the reader can have a global view of Guinevere's communication.

Therefore, this chapter aims at presenting how marketing and communication will be used in order to launch Guinevere's product on the market.

5.1 Brand Positioning

Communication can only be effective and serve a company's interest if the team behind it manages to create a consistent alignment between a whole set of different elements. In order for communication to help a company reach its goal, and succeeding in its mission, it is necessary to build a coherent flow, made of different steps that the communication team will follow (Agie & Goedseels, 2018). This is especially important since effective communication allows marketers and communication professionals to create and maintain an emotional link with customers and may enhance the value of their brand. Through communication, marketers can cement their brand name in the mind of their target

customers to encourage them to buy their products (Banerjee, 2009). There lies the whole purpose of this plan: creating a link between Guinevere and its customers to set up a profitable company.

The first step that must be tackled is the brand positioning, meaning how Guinevere's brand will be positioned on the market and in the mind of its stakeholders. To communicate effectively, it is first necessary to know what the company identity is and how its target audience need to perceive it.

Brand positioning can refer to the place a product occupies on a given market, which can be related to a market structure study, as well as the concepts of substitution and competition among products answering the same needs (Herrmann & Huber, 2000). However, in this section, brand positioning is considered from a marketing point of view, which is not what is done to a product but what is done to the mind of a prospect and therefore focuses on consumers' perceptions of the place a brand has acquired on its market (Herrmann & Huber, 2000; Trout & Ries, 1986).

Those perceptions give birth to mental attitudes as well as real behaviors towards the brand in question (Peter & Olson, 1990). According to Herrmann and Huber (2000), brand positioning can be assessed by measuring consumers' perceptions and preferences for the given brand compared to its competitors that are active on the market, which means that brand positioning has an impact on the amount of customers a company can acquire. This fact matters even more today since the market is going through an increasing complexity, and marketers must be able to cut through the noise of competing products in order to earn the attention of their target customers (Manhas, 2010).

Due to both the globalization and the development of information and communication technologies, thousands of companies are now competing for customers' attention. From the companies' point of view, it is therefore necessary to develop a strong identity, and have a recognizable position on the market, in order to be different and stand out from the crowd (Banerjee, 2009). From the customers' point of view, this growth in the amount of brand choice has created confusion, and it is necessary for them to be able to identify quickly the providers from which they will be able to buy the products and services answering their needs (Manhas, 2010).

According to Thompson (2017), the basic process of brand positioning involves different points, which are:

- Understanding the company's stakeholders;
- An active definition of the company's position;
- The creation of a brand platform;

- The expression of the platform and the position through verbal and visual identity;
- The application of a brand architecture system;
- The continuous development, management, and evaluation of the positioning over time.

This process can be summed up as follows :

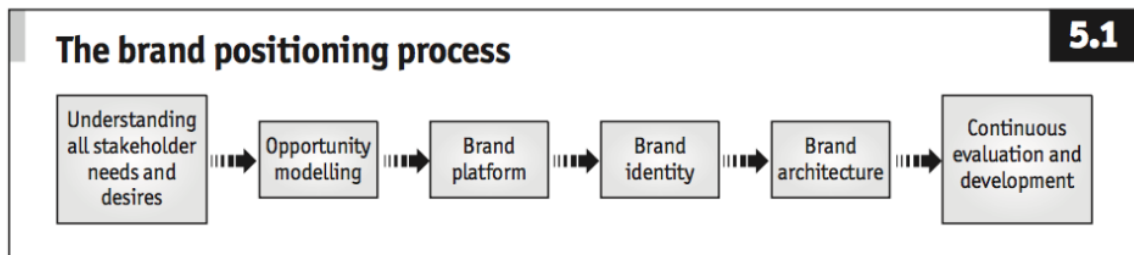


Figure 5.1: Brand Positioning Process (Thompson, 2003).

In the following pages, the four first steps of this process are tackled in order to define the brand positioning of Guinevere, which will then allow to deep dive into the marketing and communication plan of the company.

5.1.1 Defining Stakeholders

As shown in the previous figure, brand positioning begins with identifying a company's stakeholders, assessing their respective importance for the company, and defining the ideal relationship that is needed with each of them to reach business goals (Thompson, 2003). As a reminder, a stakeholder is an entity, whether it is an individual or an organization, that is not only impacted by a company's activities but that can also have an impact on those activities and therefore the company's results (Agie & Goedseels, 2018).

Precisely because of this interdependency, interactions with stakeholders during a brand positioning are crucial and should not be neglected (Gregory, 2007). Considering the value proposition of Guinevere, the following stakeholders can be cited: Hospitals; Surgeons; The Minister of Health and Ministry of Public Health; Science & Health Magazines; Universities & Research Departments; Journalists; Suppliers; Patients; Investors, Business Angels & VC's; Competitors.

Three of those stakeholders are of main importance: hospitals, surgeons, and competitors.

- Hospitals because it is their direction and administration who will decide to buy Guinevere's product;

- Surgeons because the company aims to solve the problem of maintaining sterility and save time in the operating rooms while interacting with medical imaging. For Guinevere to be profitable, its brand positioning must convince surgeons that its product can meet their needs. The long-term goal would be for the company's brand to turn surgeons into ambassadors of Guinevere's technology, which would help in convincing hospitals to buy the product more easily;
- Competitors because it is necessary to understand their positioning in order to create something different, a brand that stands out and that is not like the others.

As for the other stakeholders, here is why they should also be taken in consideration:

- The Minister of Health and Ministry of Public Health because as an innovative MedTech company, it is important to develop positive relationships with the public authority that is directly related to Guinevere's market. If hospitals happen to be interested, but do not have the funds to buy a gesture recognition tool, being well-known among the Ministry of Public Health may help target customers to get backed up by public funding;
- Science & Health Magazines should be considered for the sole purpose of brand visibility and credibility. Being featured in a serious publication, or in many different articles regarding science and health, will help in building a stronger brand and establishing the credibility necessary to acquire customers;
- The same goes for Universities and Research Departments. For a company, being able to say that it has the support coming from a university research program can be of great help in establishing brand credibility;
- Journalists because with the development of the startup nation trends, innovative companies recently founded are regularly being highlighted in the press. Therefore, journalists should be considered as a relevant stakeholder considering the visibility a press coverage can generate for a company;
- Suppliers, meaning Leap Motion since their sensor will be used, should be considered as well. As a physical product will be provided to Guinevere's clients, taking suppliers into consideration and prepare plans if they happen to not be able to supply the company anymore is necessary. The current Covid-19 pandemic is a great example as such, with Chinese factories being shut down for several weeks, many companies saw their supply chains compromised;
- Patients should be considered as well, since they are the ones who will indirectly benefit from Guinevere's value proposition and are the ones on whom surgery will be performed;

- Investors should also be considered in the case Guinevere needs funding for its good development. If such a situation happens, disposing of a strong brand positioning will help in the good conduction of a financing round;

Therefore, those 10 stakeholders should be taken into consideration, but with a focus pointed at hospitals, surgeons, and competitors.

5.1.2 Defining the Brand's Position

According to Thompson, brand managers should focus on four key principles to identify and justify an interesting positioning that will help their brand in achieving its business goals (Thompson, 2003):

- **Relevance:** strong brands manage to meet both functional and emotional needs. By understanding how a target audience defines ideal user experiences, what they are missing from existing products can be determined, and it is therefore possible to identify opportunities of unclaimed brand positioning (Thompson, 2003);
- **Differentiation:** strong brands add value and stand out from the crowd of competition. By understanding the competitive landscape, as well as the customers' perceptions and needs, it is possible to identify how to make a brand different (Thompson, 2003);
- **Credibility:** For customers to be loyal, brands must be able to keep their promises. Therefore, in the process of establishing Guinevere's brand as the leader of its market, the effectiveness of its product and the user experience it can provide should always be taken into consideration (Thompson, 2003);
- **Stretch:** A brand's success not only lies in its ability to remain relevant in an ever-evolving competitive landscape, but also in its ability to keep innovating and bringing new products into its value proposition. Therefore, a strong brand positioning is also related to the capacity of the brand to remain innovative and to constantly bring new value to its customers (Thompson, 2003);

At the center of those four elements lies a brand positioning opportunity, as it is represented in the following figure:

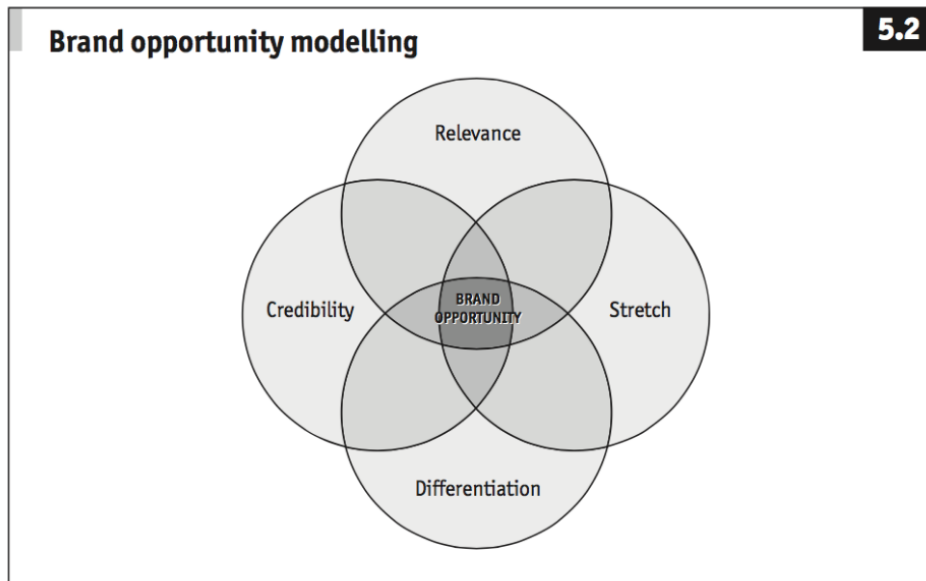


Figure 5.2: Brand Opportunity Modelling (Thompson, 2003).

Those four elements can be applied on how Guinevere should position itself in order to convince hospitals and surgeons to use its product.

Relevance implies to have a deep understanding of surgeons, their needs and their way of working with medical imagery. It is possible to say that their main need is to be able to interact smoothly with medical imagery while they are performing surgery. Guinevere should therefore be perceived as a brand making their task easier on a daily basis and taking away the pain of having to ask another person to navigate the medical imagery. As a brand, Guinevere should put the value proposition that's allowing to solve this pain point at the center of its messages, putting the needs of its customers at the heart of its communication in order to be perceived as a partner on which surgeons can rely.

Differentiation implies to make the brand different from its competitors, which can happen through both its visual identity and its tone of voice. Guinevere has two direct competitors that should be considered for its brand positioning: TedCas and aeroTAP.

- As presented earlier, TedCas seems to be the most important actor on the market as their company only focuses on gesture recognition in operating rooms, counts the largest number of employees, and has a strong online presence and activity. From a brand positioning and communication point of view, their website features three surgeons' testimonials related to the usefulness of TedCas' product. Furthermore, a video of a live surgery also shows surgeons using the solution released by the company.

Marlies Schijven, one of the three surgeons testifying on their website, is also the

president of the WATCH-Society (WearAble TeCHnology in Healthcare Society) which allows to understand that TedCas' brand is not only developing a strong relationship with its core audience but is also relying on the credibility of some members of that audience in order to improve its own brand credibility.

This is a strong strategy considering the fact that consumers are influenced in their product choices by online recommendations (Senecal & Nantel, 2004). Doing the same for further developments of Guinevere's brand should be considered. It would allow the company to show it is being trusted by its customers and allows them to have better results, which would then lead to an easier customer acquisition. If surgeons see that their peers are satisfied with a product, and testify of its efficiency, it will play a role in their own adoption of the product.

Furthermore, from a visual point of view, TedCas is using white, light blue and light grey as brand colors, in order to refer to the medical landscape, as well as using an icon and wordmark logo.



Figure 5.3: TedCas' Logo (Tedcas, 2020).

- aeroTAP is a Japanese company that is part of the group nextEDGE Technology. The company is in collaboration with the University of Tsukuba Hospital and is selling its solution as a way to preserve sterility in operating rooms. The interesting thing about this company is that rather than only focusing on the medical field like TedCas does, aeroTAP focuses on gesture recognition in general. The company offers solutions in bureaucratic and signs recognition but also code for developers so they can create more easily their own applications for gesture recognition. From a brand positioning perspective, this gives Guinevere an advantage as it is focused on one specific field, the medical one, which will allow it to develop a niche brand with a highly specialized communication. The disadvantage of a brand targeting multiple markets at the same time is the constrained ability to develop a strong relationship with a specific stakeholder, while focusing on one market allows to go deeper into that specific relationship.

That will allow Guinevere to make itself different from aeroTAP. However, their collaboration with the University of Tsukuba Hospital is an interesting aspect that should be taken into account for future brand positioning efforts. Indeed, being able

to display a collaboration with a university hospital is a credibility factor that should not be neglected in order to acquire a stronger brand positioning. Furthermore, aeroTAP's website could really use a redesign, in order to have a better visual identity, and this is a liability that could be used to position Guinevere as a stronger actor on the market of touchless interaction.



Figure 5.4: aeroTAP's Logo (aeroTAP, 2020).

Credibility is based on the performance and efficiency the product will be able to deliver and implies that brand positioning is deeply related to product development and not only marketing. The relationship a brand is building with its stakeholders is built through every interactions those stakeholders are having with the brand in question, whether it is when they use the products and services made available by the company, when they communicate with the company's employees, when they receive promotional messages, etc. A brand is not only created thanks to marketing, and therefore Guinevere should always strive to improve its products and provide an outstanding user experience in order to acquire a leader position in its stakeholders' mind.

Stretch should be taken into consideration for the future of the brand and reminds the management team that a product is never finished. In a highly competitive environment, building a brand positioning is a constant struggle, which can be tackled by the development of innovative products and value creation for customers. Not only is innovation necessary to remain relevant on the market, and avoid being disrupted by a potential new entrant, but according to *Deloitte Global Millennial Survey 2019* (2019), it is also considered as one of the main goals businesses should try to achieve by one third of the Millennials' generation. This means that as a brand, Guinevere must be perceived as an innovative company, thanks to the products and services it will release, but also thanks to the communication and marketing messages that will be created around those products and services.

5.1.3 Defining the Brand Platform

Creating a brand platform is based on an ambition or aspiration the brand is trying to achieve and that is relevant for its target audience. As the global market is evolving faster than ever before, and the speed of innovation has increased competitors' ability to copy

one another, it is now necessary for brands to have a strong platform allowing them to stand out and communicate effectively on what they try to achieve (Thompson, 2003).

That platform is built around three key elements, which are the vision, the mission and the values. The vision gives the brand a reason for existing, the mission gives it a goal to reach, while values guide all the actions undertaken by the brand. It can be represented by the following figure:

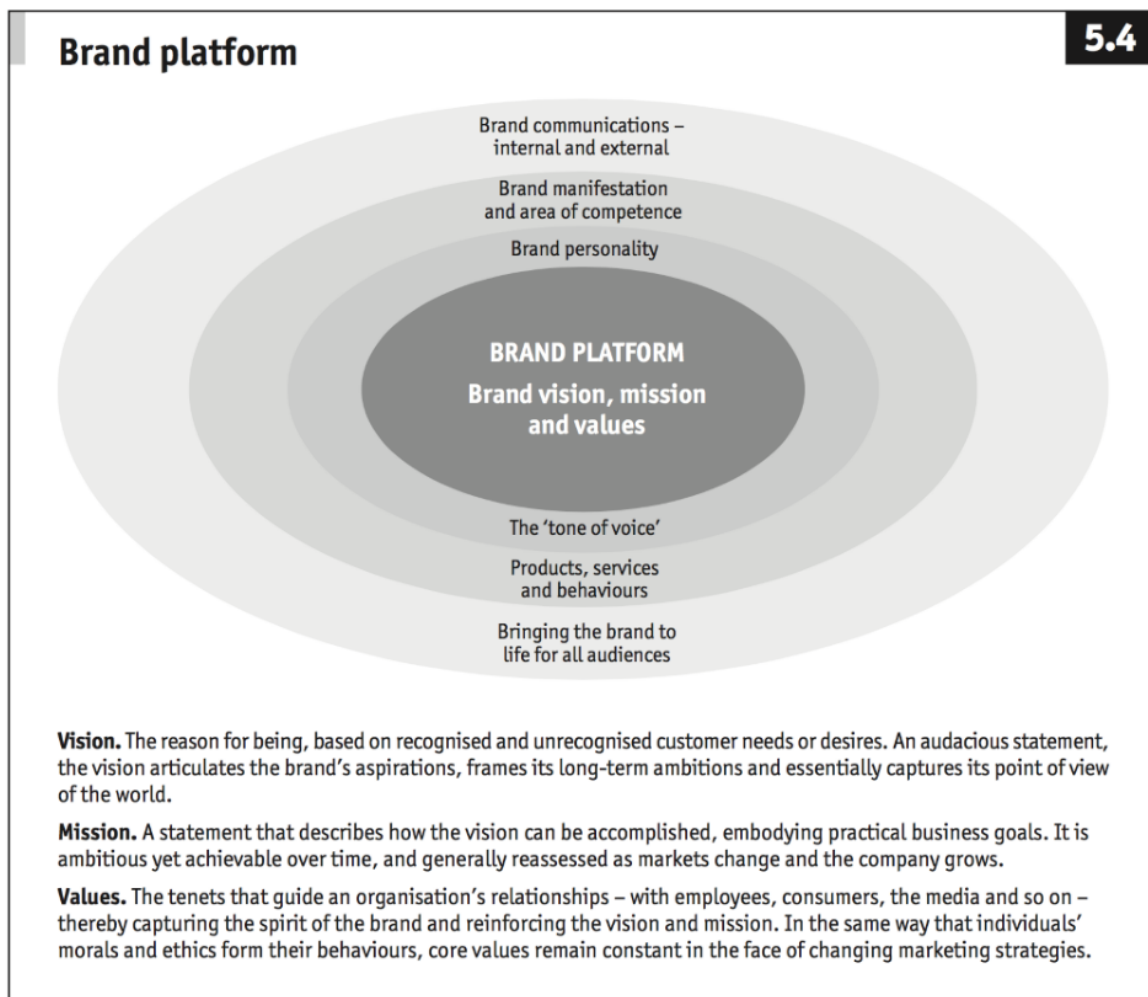


Figure 5.5: Brand Platform Model (Thompson, 2003).

As those three elements were explained in chapter 2 of this thesis, they will not be covered again in this section.

5.1.4 Defining the Brand Identity

All this introspection work around the definition of Guinevere's brand positioning has led to this point, where Guinevere's brand identity is presented. This identity is what translate words and thoughts into visual elements.

This brand identity aims at materializing how Guinevere's target audiences should perceive its brand: Guinevere is an innovative company, aiming to facilitate the way surgeons can perform their mission, thanks to touchless technology. It must be perceived as a partner on which surgeons can rely and as a serious actor on the touchless market.

In order to achieve such a positioning, a wordmark logo was designed, meaning that the company's name is used as a logo in order for people to easily remember Guinevere's name:



Figure 5.6: Guinevere's logo

As for the innovative aspect, a futuristic font was chosen, witnessing of the brand's will to challenge the way things are done on its market.

Regarding brand colors, five of them were chosen, as depicted in figure 5.7:



Figure 5.7: Brand colors

The dark and duck blue have been chosen in order to create the seriousness and credibility of Guinevere, as well as translate the peace of mind its customers will experience while using the product.

The light grey and white have been chosen in reference to the medical market and hospitals' universe but also to materialize sterility, hygiene and safety Guinevere wants to preserve in operating rooms.

As for the orange, it has been chosen as the color allowing to demonstrate the youth of the managing team, its will to challenge things in an innovative way, and have this slight touch of boldness presented in the core values.

The reader may have noticed it is those colors that were used for the customization of every table presented in this thesis.

5.2 Business and Communication Objectives

The righteous development of a communication plan starts with a clear goal to reach. It is necessary to know what the company is trying to achieve when communication is used as a tool, as we do not communicate for the sake of communicating (Agie & Goedseels, 2018).

In this dynamic, a communication objective will always be based on a company's objective, since communication serves as a tool helping companies reach their business goals (Agie & Goedseels, 2018). It is then necessary to know the company's goal to be able to define the communication's goal.

In Guinevere's case, the business objective is to generate the first sales to test the responsiveness of the market and see if the creation of a profitable company could be done. Based on that, communication should try to reach an awareness and conversion objective, meaning that all communication efforts should be oriented towards creating awareness and visibility around Guinevere's product among its target audience, which would then allow to imply a dialogue with a couple of potential customers.

If communication manages to effectively create awareness and visibility around Guinevere, it would be easier for the company to reach its business objectives of making its first sales.

5.3 Audience and Target Stakeholders

The next step is to define more precisely the target audience and stakeholders. In order to be able to raise awareness and visibility around Guinevere, understanding the audience is necessary as a great product means nothing if it doesn't get the attention of the people who would benefit from it. Furthermore, knowing the audience allows to define what are the best ways to reach it.

This knowledge implies knowing where the audience is consuming information, to which information channels it grants its time and attention, and towards which kind of messages it tends to be more sensitive.

As presented earlier, it was decided to put a focus on surgeons and hospitals, as they are the ones to whom Guinevere sells its value proposition. Understanding this audience will help in defining the messaging as well as the channels that will be used to send those messages. To define those two points, which are depicted here under, we based ourselves on Louis-Philippe Broze's intervention during UStart's Medical entrepreneurship webinar (Broze & Henry, 2020). Louis-Philippe Broze is the co-founder of Spentys, a Belgian startup developing 3D-printed orthopedics. Over the last few years, Spentys has been able

to create partnerships with a couple of hospitals, and their insights were useful to build this marketing and communication plan.

5.4 Key Messages

It was decided to focus Guinevere's key messages on three main components.

First, putting forward the efficiency of the product, and market the benefits its usage implies for the target customers. Just like Jamie Tremaine, CEO of GestSure, does it in his pitch when he presents the time and cost saving allowed by his product. Hence why it has been decided to put the benefits of the product at the center of the messaging, by doubling down on what is called Product Marketing.

Product Marketing is not just about designing a product's positioning and messaging, but it is also about ensuring the customers understand it and know how to use it (Kolowich, 2019). By doing so and allowing customers to know the benefits of the product, this specific Marketing expertise aims at driving the demand and usage of the concerned product (Kolowich, 2019).

Therefore, by focusing the messages on the benefits implied by Guinevere's solution, and on how to use that solution at its maximum potential, the core audience can get familiar with the product and understand it. It will later be seen which communication tools will allow to transfer those messages to the target customers.

Following the focus being put on the benefits implied by the technology for the surgeons, the spotlight will also be put on the benefits implied for the patients on whom surgery is being performed.

Patients will indirectly be benefiting from surgeons making use of touchless technology, which can be explained by the fact that if surgeons can manipulate medical imagery more easily, they can also perform surgery with less constraints and be 100% focused on the task at hand. If surgeons can do their job in better conditions, without the pain of not being able to move medical imagery just like they want to, patients will be benefiting from those conditions and therefore being taken care of better than before.

Finally, the third element used in the company's key messages will be to directly present the features surgeons will be able to access thanks to Guinevere's product. A great example of a company doing so is Motion Gestures (*Motion Gestures*, 2020). On their website page dedicated to Motion Gestures' product, the company depicts which gestures and which features its users will be able to access thanks to their solution. By using visual elements, showing both gestures and features, and by explaining those thanks to a short text, Motion Gestures is able to present their solution and to convert website visitors into

long term customers.

As explained in chapter 2, and in section 2.4.4, Guinevere could do the same by repurposing its gesture representations presented in chapter 4 and in appendix D into marketing assets.

More concretely, Guinevere's website should have a dedicated product page where visitors will be able to see what kind of gestures Guinevere offers for which kind of features. The reader will be able to find an example in figure H.4, where one of Guinevere's gesture representations is depicted. Of course, those figures are only prototypes and it would be necessary to collaborate with an agency specialized in graphic design in order to create more attractive gesture representations to increase their marketing performances.

5.5 Tools

In order to reach the awareness and conversion objective, it is necessary to use a couple of tools to send the messages towards the target audience. In the context of this thesis, a set of three different tools could be used and aligned with Guinevere's global strategy.

The first tool is a website that would be backed up by a blog dedicated to the product and its advantages. The website would allow to present the product, the gestures and the features like Motion Gestures does it, the benefits implied by touchless interaction and gesture recognition, as well as being a place where references would be featured. Those references can be the support provided by academic partners, media mentions, as well as customer reviews coming from surgeons who tried the product.

Regarding the blog, it would be the place where all the content could be published, meaning tutorials on how to best use the product, information about gesture recognition, the future of surgery, the updates of the product and the progress made by the managing team. This blog could be a logbook depicting Guinevere's story.

Using a website and a blog consists in leveraging Content Marketing to diffuse messages the core audience can then consume. Content Marketing can be defined as a strategy relying on the creation and diffusion of valuable, useful and informative content in order to communicate with an audience and develop a product's visibility (HubSpot, 2020).

The second tool that will be used is LinkedIn coupled with e-mailing. Since Guinevere is targeting a very niche market, LinkedIn's search box could be leveraged to find surgeons and hospitals representatives. It would then be necessary to scrape their email addresses as well as study their professional careers to better know how to approach them and present them Guinevere's solution. Once a certain amount of potential customers can be reached out to, with a minimum knowledge of who they are and what they did in their careers,

personalized messages will be directly sent to their email addresses. The aim of those messages will be to trigger a reaction and set as many sales meeting as possible.

Finally, the third tool is public relations, that would eventually allow Guinevere to be featured in the general and specialized press. The goal here would be to achieve an awareness campaign through the press in order to be better visible among the target audience. In order to be featured in the press, press releases as well as directly contacting journalists who might be interested in Guinevere's story may be an effective strategy.

5.6 Strategy

A strategy is a method, or a plan, chosen to reach a desired future such as achieving a goal or solving a problem (Agie & Goedseels, 2018). As depicted earlier, Guinevere's communication strategy consists in combining both wide and precise tools to communicate product-oriented information towards a niche market made of surgeons and health professionals.

Those tools were chosen because they were the most relevant ones regarding the target market and the potential customers. It's those two variables that really defined the strategic choices made earlier, and would they have happened to be different, the strategy would not be the same.

When it makes sense to combine a website and a blog with LinkedIn and emailing to contact health professionals and present them a touchless technology for medical imagery control, as well as using public relations to gain credibility, this strategy would not be adapted at all if the Guinevere project was different. If Guinevere was a direct-to-consumer e-commerce selling health complements for men and women aged from 18 to 25 years old, the communication tools would have been completely different.

In such a scenario, the choices would have been oriented towards the creation of a web shop enabling the sales of the products combined with a blog aiming at ranking first on the Google Search Results Pages for keywords related to the products. That blog would have been made up of articles targeting keywords related to health and well-being, in order to drive traffic and acquire customers among this traffic. To identify interesting keywords, tools such as SEMRush, Ahrefs or Similarweb could have been used to analyze which keywords have the biggest volumes, and therefore know which articles to write and publish in order to have the most chances to drive traffic on Guinevere's blog. Furthermore, it could have been possible to use some budget for social advertising on platforms such as Instagram and Facebook, directly targeting men and women aged 18 to 25 years old, in order to drive conversions. Instagram would have been particularly useful, as the company could have partnered with Be Influence to work with nano and micro influencers with

audiences interested in health and well-being.

This counter example shows how much an audience and a product have an impact on the communication strategic choices that must be made. Even though the goals are the same in both cases, which is to raise awareness and drive the first sales, the considered tools are totally different.

Targeting keywords for blog articles to generate large traffic, using social advertising on Instagram and Facebook, and partnering with influencers would be non-sense for Guinevere's real value proposition, precisely because it is aiming at a niche market that cannot be reached with those tools. In order to reach the communication objective, the tools that were chosen and formerly presented are far more adapted.

5.7 Budget

The main expenditure item in this marketing and communication plan is the creation and maintenance of a website, which includes different costs.

First, the acquisition of the domain name guinevere.io and its web hosting by OVH.com will cost €181 per year (see appendix H.1).

Second, the creation of mockups in order to create the visual identity of the website will cost €110, made by a graphic design freelancer on Fiverr (see from appendix H.2 to appendix H.5).

Third, the creation of a professional looking website on WordPress, with all its functionalities included and the implementation of the branded mockups, will cost around €1500.

Therefore, for the first year of existence of Guinevere, a budget of €2000 for the creation of the project's website should be prepared.

Furthermore, regarding the two other tools presented earlier, meaning LinkedIn combined with emailing and outreaching journalists through public relations, the costs are estimated to be €0.

Indeed, using LinkedIn and a mailbox such as Gmail to contact surgeons and give them information about Guinevere's product does not imply any cost. In the same dynamic, outreaching and contacting journalists by sending them a press release or asking them for an interview does not imply any financial cost. On the other hand, those two methods imply heavy time investments. Whether it is finding the right people to contact, studying their careers in order to know how to address to them, and writing personalized impactful

messages, all of those steps involve time and are requesting persistence in order to be effective.

Therefore, the chosen tools for this communication plan present the advantage of not implying heavy financial costs, which are limited to €2000, but they do request time investments as well as serious work in order to get the expected results.

5.8 Key Performance Indicators

Let's now consider the key performance indicators that should be monitored in order to assess the efficiency of this plan. Indeed, there is no point in undertaking marketing and communication actions without knowing how to evaluate their results. Being aware of those results is critical in order to adjust the communication efforts in real time and have more chances of success.

Here is a list of indicators that would allow to assess the efficiency of the plan:

- The amount of impressions the website manages to have on Google;
- The amount of traffic the website manages to acquire;
- The amount of mails being sent to surgeons and hospitals representatives;
- The amount of answers received from surgeons to whom an email was sent;
- The amount of meetings set up with target customers;
- The amount of positive replies from journalists agreeing to give Guinevere some press exposure.

Monitoring all those indicators will show if the plan is effective or not, and will therefore allow to know if it is necessary to adjust the actions in order to reach the communication objective.

5.9 Conclusion

This chapter aimed at better defining Guinevere's brand, as well as its communication plan. The goal was to present a strategy that would allow the company to make itself different from competitors presented in chapter 3 as well as defining what would be the best way to reach its key stakeholders. Furthermore, the brand colors presented in this chapter were also used to customize every table of this thesis.

Marketing and Communication Plan		
Brand Positionning	Stakeholders	Competitors, Surgeons, and Hospitals
	Brand Identity	Defined by the logo and the brand's colors
Business and Communication Objectives		Generate the first sales to test the responsiveness of the market and see if the creation of a profitable company could be done.
Key Messages		The benefits implied by Guinevere's solution.
Tools		1) Blog dedicated to the product and its advantages ; 2) LinkedIn coupled with e-mailing ; 3) Public Relations that would eventually allow Guinevere to be featured in the general and specialized press.
Budget		€2000
Key Performance Indicators		1) The amount of impressions the website manages to have on Google ; 2) The amount of traffic the website manages to acquire ; 3) The amount of mails being sent to surgeons and hospitals representatives ; 4) The amount of answers received from surgeons to whom an email was sent ; 5) The amount of meetings set up with target customers ; 6) The amount of positive replies from journalists agreeing to give Guinevere some press exposure.

CHAPTER

6

LEGAL & ADMINISTRATIVE ANALYSIS

In this chapter, Guinevere’s team and the roles of its members are first introduced. Then, the advantages of creating a legal personality as well as the limited liability status are discussed. The formalities to be completed in order to create a company are then presented as well as Guinevere SRL and its characteristics. Furthermore, this chapter also discusses the intellectual property stakes behind Guinevere’s technology and the different steps that must be followed in order to submit a patent.

6.1 Guinevere’s Human Resources

6.1.1 Role Distribution between the Founders

Jean Wilberz will be CEO (*Chief Executive Officer*). He will be responsible to lead Guinevere’s team and have an eye on all the different aspects of the project, but he will also be the one to make the decisions in situations where a consensus cannot be found. Considering Jean’s previous entrepreneurial experiences, and his role as UStart LLN President between 2018 and 2019, he was the most relevant to take on this role.

Bastien Nothomb will be CTO (*Chief Technical Officer*). He will be responsible for the research and development as well as for all the technical aspects related to Guinevere. Considering Bastien’s skills and his role in the development of Guinevere’s product, that choice was obvious.

Harry Usuwiel will be CFO (*Chief Finance Officer*). He will be responsible to handle Guinevere's finances and make sure the company remains profitable. Furthermore, Harry will also be responsible for Guinevere's legal status and will be the person of reference for all legal matters. Considering Harry's skills in finance and accounting, as well as his background in economics, that choice made perfect sense.

Tancrède d'Aspremont Lynden will be CMO (*Chief Marketing Officer*). He will be responsible of Guinevere's visibility and reputation on the market. Tancrède will have to develop the right strategies for Guinevere to be able to reach its target users as well as develop a positive relationship with them, namely by leveraging the right marketing tools.

6.1.2 Coaching & Supporting Committee

With the team's short experience as entrepreneurs, the creation of a supporting committee should be considered, by bringing together different people whose experiences could help in the right development of Guinevere. Among those coaches, we should find experts coming from different areas, such as touchless technology of course, but also medical entrepreneurship, digital marketing, and human resources.

The aim would be to allow the team to have a board of coaches towards whom we could turn ourselves in challenging situations. For instance, if we want to improve our product and go further into gesture recognition, having a coach specialized in this specific area would be of great interest. In the same manner, if we have questions regarding marketing strategies, being able to ask those to an experienced marketing professional would allow us to have better results and avoid mistakes. Therefore, creating such a committee would be of great interest.

6.1.3 Employees & Collaborators

It is probable that if Guinevere becomes profitable, the company will need more people to join its ranks in order to grow properly. Regarding this specific point, it is of high importance to take the time necessary to define what kind of people would fit inside of Guinevere. A company is made up by the people who run it, who promote and sell its products, who share a common vision and have the same goal. A bad hiring decision, and choosing an employee with whom there is no cultural fit, could hurt the company's health. Therefore, choosing the right people, as well as creating a professional environment where everyone can thrive, will be a serious matter.

Indeed, mental health and fulfillment at work is becoming a topic of great interest among the different actors of the entrepreneurial landscape, and we want to position Guinevere rightfully regarding this emerging trend. A report published by CB Insights

revealed that mental health mentions have become more and more common inside financial reports made by companies, especially during the last quarter of 2019 (CB Insights, 2019).

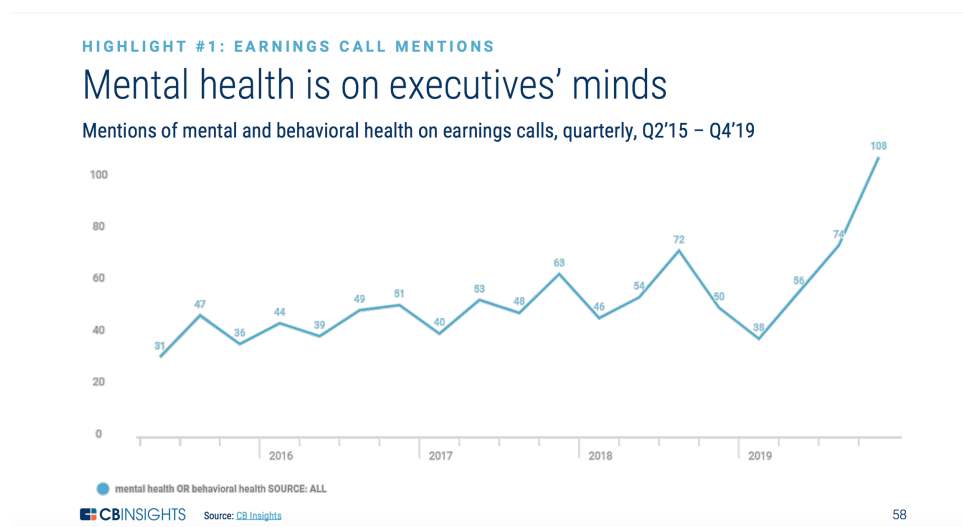


Figure 6.1: State of Healthcare: Investment / Sector Trends To Watch (CB Insights, 2019).

In Europe, mental health problems lived by workers cost on average 600 billion euros per year (OECD, 2018). Hence the fact that a growing number of companies are creating solutions to resolve those mental health problems experienced by employees. Among those companies, *Calm* and *Headspace* who offer meditation programs, as well as *Hinge Health* who offers digital solutions for companies with employees experiencing musculoskeletal disorders, can be cited. Other companies such as *Unmind*, *Maven* and *Spill* should not be forgotten either.

The mental health startups landscape is super active, and Venture Capitalists have a role to play. Indeed, in 2019, VC's invested \$580 million in mental health startups, when they only invested \$120 million in 2014 (Octopus Group, 2020). Among the companies cited earlier, *Maven* raised \$83.7 million, *Spill* raised \$650 thousand, *Unmind* raised \$16.2 million, and *Hinge Health* raised \$126 million for an estimated yearly sales turnover of \$43.5 million. All those numbers and trends show that employees' wellness at work is becoming a crucial matter, not only for their overall well-being, but also for the loyalty they have towards their employers.

Therefore, when we will hire new team members, not only will we choose them with great attention in order to be sure there is a human and cultural fit, but we will also make sure they can work in an environment where they feel the company wants to take care of them.

6.2 Creating a Legal Entity

6.2.1 Advantages of Creating a Company

The first advantage of creating a legal personality is the fact that it has its own patrimony and rights as well as obligations distinct from its founders'. This advantage is paramount as we believe it is essential for our personal liability to be limited (Malherbe, 2020). Creating a company will limit our stake and limit our commitment. This means that the company's creditors will only be able to call on the company's assets and not on the partners' private assets (SPF Economie, 2019a).

Moreover, creating a legal personality is also more interesting in terms of taxation. Indeed, a company is subject to the corporate tax system, which is lower and less progressive than the personal income tax system. Therefore, if the company's profits are significant, it is fiscally advantageous to be taxed under the corporate system. However, the incorporation of a company requires to comply with legal and administrative obligations such as the completion of a financial plan, the drafting of the articles of association or a report from the auditor in the case of a contribution in kind (Malherbe, 2020).

As creating a company seems to be an obvious decision for Guinevere, a choice was made towards the limited liability status, which is discussed in the following section (SPF Economie, 2019a).

6.2.2 The Limited Liability Company (SRL)

As the team is young and lacking in substance, it was decided to incorporate an SRL. Indeed, we are not in a position to contribute the capital needed to establish an SA as article 7:2 stipulates that the capital may not be less than €61 500 (CSA, art. 7:2).

In the following lines, what is involved by setting up an SRL is presented. The SRL has its own legal personality. Its capital is divided into shares and the shareholders jointly hold 100% of those shares. Moreover, the shareholders' liability is limited to the contributions they have made. In addition, the *code des sociétés et des associations* allows the transfer of shares of an SRL provided that it is explicitly stipulated in the company's articles of association. One of the big advantages of the SRL is that its incorporation no longer requires the contribution and payment of a minimum capital (it previously was €18 550 for SPRL's, of which €6 200 had to be paid upon incorporation). In addition, this type of company can be incorporated alone, with one associate, or with multiple associates (Liantis, 2020).

Nevertheless, this kind of company still has its drawbacks. Indeed, even before the incorporation, a financial plan must be presented to a notary, in order to justify the

amount of the initial equity capital according to the activity provided for a period of at least two years. As article 5:3 confirms, *"The founders shall ensure that the limited liability company has, at the time of its incorporation, equity capital which, taking into account other sources of financing, is sufficient in the light of the planned activity"* (CSA, art. 5:3). Another disadvantage of the SRL is the fact that we will have to go to a notary and that the incorporation of this type of company is quite expensive. This will be discussed in the next section (Liantis, 2020).

6.2.3 Requirements for setting up an SRL

This section will consist of three main points: the financial plan, the incorporation deed and the VAT liability needed to establish an SRL.

Writing a financial plan that will justify the start-up capital based on the activity planned of the company for a period of at least two years will be necessary. As mentioned in article 5:4 of the *code des sociétés et des associations*: *"Prior to the incorporation of the company, the founders shall submit to the notary a financial plan in which they justify the amount of the initial capital in the light of the company's planned activity for a period of at least two years. This document is not filed with the deed, but is kept by the notary"*. This financial plan is of the utmost importance and its scrupulous implementation is therefore essential. *"The company's commitments, in the proportion fixed by the judge, in the event of bankruptcy pronounced within three years of the acquisition of legal personality, if the initial equity capital was, at the time of incorporation, manifestly insufficient to ensure the normal exercise of the planned activity for a period of at least two years, the notary shall, at the request of the official receiver or the public prosecutor, forward to the court the financial plan prescribed by virtue of article 5:4"* (CSA, art. 5:16; 5:4).

Furthermore, article 5:11 warns that the deed of incorporation of a limited liability company must be drawn up by an authentic instrument, meaning before a notary (CSA, art. 5:11). This notarial deed is mandatory for all limited liability companies: public limited companies (SA), limited liability companies (SRL), or cooperative companies (SC). The deed of incorporation contains the articles of association of the company, which determine the form of the company, the company name, the duration of the company, the registered office, the object or the capital. In addition, this memorandum of association must imperatively be deposited at the clerk's office of the company court of the registered office of our company. In Guinevere's case, it will either be in Nivelles or in Brussels. This deposit will be carried out by the notary within 30 days of the constitutive act (Notaire.be, 2020a). Finally, the deed of incorporation must also be registered in one of the registration offices of the SPF Finances, by the notary, within 15 days of the deed of incorporation (SPF Economie, 2020a).

Besides, article 4 of the *Code TVA* stipulates: *"A taxable person is anyone who, in the exercise of an economic activity, carries out, in a regular and independent manner, either as a principal or as an adjunct, with or without a profit motive, the supply of goods or services referred to in this Code, regardless of the place where the economic activity is carried out"* (Code TVA, art. 4). The company Guinevere SRL is therefore concerned by this article of the VAT Code. Therefore, we will have to go to a tax office or to the competent company counter in order to have a VAT identification number including the letters BE (Code TVA, art. 50).

6.2.4 Characteristics of Guinevere SRL

In this part of the thesis, the identifying clauses are discussed in more details: the corporate name, the registered office and the nationality but also the corporate object and the life span of Guinevere SRL.

Registered name

According to the FPS Economy, the company name is *"the official name of the legal person (S.A. or SRL for example), which is included in the articles of association and published in the Belgian Monitor. The corporate name therefore identifies the legal entity and, unlike the trade name, has no marketing function. Whoever first acquires a company name has an exclusive right to that name for the whole of Belgium. If another company chooses a company name that is identical or whose resemblance may be misleading, it may be forced to change its name and award damages to the holder of the previous company name"* (SPF Economie, 2020b).

The name we have chosen is "Guinevere" and in order to be entirely sure that this one has not already been chosen, we decided to search in the database of the Crossroads Bank for Enterprises but also on the site of the Belgian Monitor. Following these searches, no company with the name *Guinevere* was identified in Belgium. This company name will also be a trade name.

Furthermore, this corporate name and legal form must appear in *"All deeds, invoices, announcements, publications, letters, order notes, websites and other documents, whether in electronic form or not, emanating from a legal entity"* (CSA, art. 2:20).

Corporate purpose and lifespan

The object of a business is the activity that the partners will carry out together. Moreover, it also points out that *"the law requires the founders to take over the "precise designation" of the company's object. It is sufficient to determine the type of economic activity that the*

partnership will carry on" (Notaire.be, 2020b). It is also important to specify that the company may not carry out any activity not provided for in its corporate purpose.

It is with this perspective in mind that we have described the corporate purpose for Guinevere SRL as: "The purpose of the company is the sale and provision of a gesture recognizer as well as a computer software enabling the use of the said recognizer."

Furthermore, it is important to keep a broad scope of the company's purpose, in order to avoid overshooting but also to be able to pivot if necessary. Companies can still modify or extend this object. Indeed, this modification is possible but is very constraining: *"Prior to the holding of this meeting, the representatives of the company will have to draw up a detailed report in which they justify the proposed modifications, and they will have to attach to it a recent financial situation of the company (statement dating back no more than 3 months). These formalities are cumbersome: for this reason, it is far preferable to think about all possible activities at the time of the company's incorporation provided that the financial plan is adapted to these activities or specifies the date on which these activities will be carried out"* (Notaire.be, 2020b).

Finally, regarding the lifespan of the company, it is unlimited.

Head office and nationality

The registered office of a company is considered to be its domicile. It is the place where certain formalities, such as the filing of the memorandum of association, must be carried out. Moreover, it is in this same place that all events in the life of the company, such as meetings of the general assembly, must take place and, finally, where procedural acts must be carried out (Malherbe, 2020). The law of the country in which the effective registered office is incorporated is applied to the company (*lex societatis*). Thus, under article 110 of the Code of Private International Law, any organization with a real registered office in Belgium is governed by Belgian law. The rule is that the statutory seat must refer to the company's real registered office, i.e. the company's principal place of business. More specifically, it refers to the place from which the company is managed and where its bodies meet (Malherbe, 2020).

Guinevere SRL will be founded in Belgium, more particularly in Wallonia, and will therefore be subject to Belgian regulations.

Capital

Regarding capital, the new *code des sociétés et des associations* no longer provides a minimum capital requirement for SRLs. However, it will still be necessary to raise a sufficiently large amount of capital so that Guinevere's activity can be carried on normally

for a period of at least two years. *"Unless otherwise stipulated in the memorandum of association, all contributions are fully paid up upon incorporation"* (CSA, art. 5:8). We will therefore rely on the financial plan in order to know the amount of that capital. Indeed, as explained in more depth in the Cash flow statement projection section, each of the founders will contribute the same amount of money, which is €5 000, for a total of €20 000 for the creation of the company, as presented in section 7.5.

Concerning the category of securities, it should be noted that the SRL can now also issue different types of shares, including subscription rights (old warrants) and convertible bonds. Previously, this was only possible for the public limited company. There are therefore no restrictions on the categories of securities that can be issued. However, the new law specifically provides that only shares may be sold (IPCF, 2019). In order to simplify matters, the company will opt for common shares, for which one share equals one vote.

As part of the share's distribution, Guinevere SRL will issue 100 shares to each founder and each share will have a value of €50. Ownership of the shares shall be established by an entry in the shares register. Unless otherwise provided for in the Articles of Association, each share shall have one vote and shall entitle the holder to an equal share of the profits and of the liquidation balance. In addition, the transfer of shares is, except in cases such as the sale or transfer to a shareholder, his or her spouse or immediate ascendant, or his or her descendants, subject to the approval of at least half of the shareholders holding at least three-quarters of the shares. Exceptions to this rule may also be provided for in the articles of association (Deminor, 2020).

Regarding Guinevere, we are satisfied with this rule because we want to retain control over those who would take Guinevere shares at a later date. In addition, we wish to delay the introduction of a new partner as long as possible, fearing a reduction of our independence.

Company bodies

First of all, Guinevere has four founders: Bastien Nothomb, Harry Usuwiel, Jean Wilberz, and Tancrède d'Aspremont Lynden. In order to ensure a certain continuity, these four directors will be appointed in the articles of association. Moreover, they may only be dismissed for serious reasons or with the mutual consent of the partners and are deemed to be appointed for the life of the company (CSA, art. 5:70).

Furthermore, according to article 5:73 of the *code des sociétés et des associations* : *"Each director has the power to perform all acts necessary or useful for the achievement of the company's purpose, with the exception of those reserved by law to the general meeting"* (CSA, art. 5:73). In addition, at least one ordinary general meeting must be held each

year in a limited liability company (SRL)(CSA, art. 5:100). Finally, an extraordinary general meeting may be convened on certain occasions, such as the amendment of the articles of association or the corporate purpose for instance (CSA, art. 5:100).

6.3 Intellectual Protection Rights

In this section, the submission procedure for a patent application carried out by LTTO as well as an explanation of how Guinevere is eligible for a patent application are presented. Then, the advantages and disadvantages of such a submission will be discussed as well as the evaluation of its objectives. Finally, the choice of the most appropriate patent and its practicalities are explained.

A patent is a «legal title that gives inventors the right, for a limited period (usually 20 years), to prevent others from making, using or selling their invention without their permission in the countries for which the patent has been granted» (EPO, 2020). Patents are a major asset for companies. According to the statistics published by the European Patent Office, a company like Siemens filed 2493 patents in 2018 alone, surpassing companies like Samsung (2485 patents) or Huawei (2249 patents). In addition, the same institute reveals that more than 174 317 patent applications were filed in 2018 (EPO, 2019).

Guinevere's product is based on an algorithm that has never been developed before. For this reason, the idea of patenting it in the form of a software emerged as an important issue.

6.3.1 Conditions

As the FPS Economy points out: « *To be protected by a patent, an invention must be new, inventive (involving an inventive step), susceptible of industrial application and lawful* ».

The first condition is related to the subject-matter of the patent, namely the need for the patent to be an invention. This notion is different from the notion of "discovery", which can be defined as finding something pre-existing in nature and therefore not patentable. Invention, on the other hand, requires human intervention on nature, although this intervention may be limited to assigning a function to an object, natural material or scientific law (Dusollier & Francquen, 2015). In other words, the invention is an intellectual creation with a technical character: *"any invention must have a technical character, it must provide a technical solution to a technical problem, be industrially applicable and be capable of being reproduced without excessive effort"* (EPO, 2020). Concerning Guinevere's software, it is indeed an invention because it is not a discovery and does offer a technical solution to a technical problem. This first condition is thus well respected.

The second condition concerns the novelty of the invention. The latter must be considered as new, and cannot be included in the state of the art at the present time (Code de droit économique, art. XI.6). This notion of novelty covers everything that has not yet been published (Dusollier & Francquen, 2015). To carry out such a novelty study, an anteriority study must be done in order to check whether anything similar to Guinevere's invention has already been published or not. This has already been done by Pi-square and none of the publications were really close to Guinevere's software. Therefore, the second condition seems to be respected as well.

The third condition concerns an inventive step. After the question of novelty, the question of inventive activity is a logical consequence since the activity can be recognized as inventive only if it is new (Dusollier & Francquen, 2015). In order to meet this third condition, it is imperative that the invention is not obvious and does not flow logically from prior knowledge. Besides, the invention must not be obvious to a person skilled in the art according to the state of the art, which is the case for Guinevere.

The fourth condition concerns industrial application. As the above definition details it, the invention must have an industrial application (Dusollier & Francquen, 2015). This fourth condition has been validated in the analysis of potential markets (3.2). Indeed, the latter studies the different industries in which Guinevere's product could be applied.

In conclusion, following those conditions, it seems Guinevere's product can be patented. In the following section, the advantages and disadvantages of patents are discussed.

6.3.2 Advantages and Disadvantages of the Patent

In terms of advantages, a patent gives its owner an exclusive right of prohibition. He therefore has the right to prohibit third parties from using his invention if no agreement has been reached beforehand. He also reserves the right not to use his invention and to license it (EPO, 2020). This would allow Guinevere's team to be the sole owner of this technology for a certain period of time, giving it the right to exploit this technology or simply sell a licence to the largest players in the industry.

Furthermore, the patent is a very effective way to put a project in the spotlight. Indeed, the filing of a patent will more than likely make it possible to talk about the project and will therefore generate good publicity. Moreover, it would allow the company to gain credibility (SPF Economie, 2019b).

Regarding the disadvantages, filing a patent is costly in terms of time and money. It is therefore extremely important to ensure its success. Secondly, when a patent is filed, clearly describing the invention is necessary, which means it can be consulted by anyone. This can possibly give ideas for improvement to third parties and/or give strategic information

about the company. Finally, the patent does not have an unlimited duration and in some cases, secrecy could give a much longer competitive advantage (SPF Economie, 2019b).

6.3.3 What is the Purpose of a Patent within a Company?

First, a patent allows a company to protect a new technology for future commercialization. Second, a patent can also be used to generate an asset for the company. Finally, it can increase the company's profits by giving it a monopoly (SPF Economie, 2019b).

Given the state of the Guinevere project, seeking protection to gain time to commercialize the product and prevent it from being copied is the motivation behind filling a patent. Once the commercialization will begin, the two other reasons will be considered.

6.3.4 How to File a Patent?

The introduction of a patent is a long-term process. Indeed, there are several steps to successfully filing a patent. The first is to file an application with an intellectual property office, such as the EPO, OPRI or INPI. The second step is the examination of the application, which consists of checking whether the conditions presented earlier are met. The third step is the grant of the patent. Finally, the last step is the payment of the annual maintenance fee that must be paid by any patent holder for the patent to remain valid (SPF Economie, 2019b).

In addition, the lengthy procedure for the grant of a patent is extremely costly and it is therefore necessary to ensure its success, as failure to obtain a patent can still result in significant costs. In total, a complete procedure costs approximately €24 000 (LTTO, 2019).

6.3.5 Which Patent to Apply for?

In order to optimize the cost and time of filing a patent, it is essential to decide on the procedure to be adopted, as there are different ways to do it. However, these different paths have different characteristics and certain contexts are more appropriate for one or another procedure.

In our case, we want to initially focus on Belgium because we have a gateway to this country, mainly via UCLouvain and its clinics. In a second phase, we would like to continue our expansion in European and/or non-European countries. It is therefore relevant to introduce an international patent application in order to obtain patents both in and outside Europe. To do so, an application will have to be filled at the WIPO, which manages the Patent Cooperation Treaty (PCT). One of the prominent advantages of the PCT is that it is only necessary to make a single application for a large number of countries. In addition,

the PCT gives rise to an international prior art search and possibly the verification of other requirements. In addition, all European countries are part of the PCT but also China, the United States and India (WIPO, 2020).

There are other advantages to this procedure. In addition of being easier for the company introducing it, if the company is targeting different countries internationally, this procedure is cheaper. On top of that, a 30 months-time frame is granted to better define the target countries (WIPO, 2020). This will have the consequence of postponing the costs related to the patent but also to analyze the opportunities that will be offered to Guinevere thanks to it.

6.3.6 Conclusion

In conclusion, as no law student is part of Guinevere's team, elaborating the theoretical part was necessary in order to really understand the notion of a patent. We were then able to grasp all the stakes and conditions of this aspect of the project, which can sometimes be overlooked. In the present case, this part on the patent opened our eyes to the necessity but also the feasibility of filing such a document.

6.4 Useful Contracts

Three types of contracts will be required for the Guinevere project and will be discussed in the following sections.

In the framework of Guinevere's economic activity, collaboration with different actors will be necessary. It is from those relationships that useful contracts will arise. In this section, a particular attention was paid to employment contracts and business contracts. Furthermore, the Civil Code that regulates those contracts leaves a lot of room for contractual freedom and often the provisions are suppletive. The new mandatory rules must, however, be maintained.

6.4.1 Business Contracts

This type of contract will be necessary for Guinevere SRL when providing services to hospitals. This type of contract is defined as *"the agreement by which one person, the contractor, undertakes towards another, the client, to carry out, in return for the payment of a price, a specific work or service, without alienating his independence in the material execution of his commitments or having a power of representation"* (Kohl, 2016). Moreover, still according to Benoît Kohl, the scope of application of the contract of enterprise is very broad. It may have as its object both manual and intellectual services. It is therefore easy to affirm that the contract for a software service facilitating human-machine interaction in

operating rooms as well as the accompanying change management service fits perfectly into this category of contract. Despite the extent and plurality of situations in which this type of contract can be used, the Civil Code contains only 18 articles concerning it (Kohl, 2016).

Parties' Obligations

This contract will give rise to obligations both for the service provider (Guinevere SRL) and for the clients (hospitals).

"The main obligation of the service provider is to perform the promised service" (Kohl, 2016). Guinevere will therefore have an obligation of result, which is to provide hospitals a device allowing them to control images in operating rooms with simple hand gestures. As the client, hospitals must pay the agreed price and comply with the obligations to cooperate. These include the responsibility to act in good faith and to facilitate the work.

6.4.2 Employment Contracts

If Guinevere evolves in a positive way, hiring employees will be necessary, which is why employment contracts are discussed here under. *"The contract of employment of an employee is the contract by which a worker, the employee, undertakes, in return for remuneration, to provide work mainly of an intellectual nature under the authority, (...) of an employer"* (Loi relative aux contrats de travail, art. 3).

It is therefore essential to identify three elements which constitute any contract of employment, namely the work, the remuneration and the subordination of the employee.

Parties' Obligations

From the conclusion of the employment contract arise obligations for both parties. Some of these obligations are specific to certain employment contracts or certain companies or sectors of activity. Others are much more common and are applicable to all employment contracts. "The employer and the employee owe each other mutual respect and consideration. They are obliged to ensure and observe respect for propriety and good morals during the execution of the contract» (Loi relative aux contrats de travail, art. 6).

According to this logic, Guinevere SRL will have obligations towards its workers, which are as follows: The SRL will be obliged to make its employees work under the conditions provided for in the employment contract (working time, place,...), it will also be obliged to provide the worker with everything he needs to carry out the task provided for in the contract, it will also have to take care of the worker's health and safety, and finally it will

have to pay him according to the conditions provided for (Loi relative aux contrats de travail, art. 17).

The employee will also be bound by obligations that must be respected. He will have to carry out his work properly and under the conditions provided for. He will have to act in accordance with his employer's instructions, not divulge any personal or confidential data of which he has become aware of in the course of his professional activity and, finally, ensure his own safety but also that of his colleagues, employers or third parties (Belgium.be, 2015).

6.4.3 Sales Contract

It is quite clear that Guinevere SRL will need this type of contract, especially when purchasing the devices from Leap motion, Inc. Indeed, in order to function properly, Guinevere's software will require a motion recognition device. A sale is defined as "an agreement by which one party agrees to deliver something and the other party agrees to pay for it. It can be made by authentic act, or under private signature" (Code civil, Art. 1582). Moreover, a contract of sale has the characteristics of being a named, consensual, synallagmatic, onerous and commutative contract. Moreover, in the present case, it will be a commercial contract, as it is concluded between two professionals for commercial purposes. In the following section, parties' obligations are looked into.

Parties' obligations

As with any classic sales contract, there are always certain obligations incumbent on the seller and others on the buyer. As the seller, Leap Motion Inc. will have the obligation to physically deliver the device sold and to guarantee the conformity of the product, in as it must meet the use for which it is intended (Code civil, art. 1603). The professional buyer, the company Guinevere SRL, will have two main obligations: the payment of the price and taking delivery of the product at the place and time when the seller has undertaken to deliver it (Code civil, Art. 1950).

6.5 Liability in case of Product Defect

In this section Guinevere's liability for product defects will be identified. This will be done by carrying out a damage analysis and an analysis of the insurance that the company will require.

6.5.1 Case of Damages

If such a complaint occurs, Guinevere should identify the provenance of the issue to judge if its liability is involved or not. Indeed, Guinevere's solution will involve third party products such as the sensor (Leap Motion), the computer, the DICOM viewer and the display screen. Guinevere's solution consists in the connection of those elements and the integration of a software to ensure the gesture recognition and translation into actions, which in case of defect, will be the company's responsibility.

The first article of the law of February 25th, 1991 relative to the responsibility in case of defective products states that *"The producer is responsible for the damage caused by a default of the product"* (Loi relative à la responsabilité du fait des produits défectueux, art. 1). This clearly states that in case of the default of one of the components of Guinevere's solution, the team can turn against the producer and it will not impact Guinevere's responsibility.

If each component of third-party products is functioning, there remains Guinevere's responsibility for the coordination happening between them. In case of a defect in it, this would be the company's responsibility and *"the proof of the defect, the damage and the causal link between the defect and the damage shall be incumbent on the injured party"*. Therefore, those damages will have to be presented from the hospital to us to point out our responsibility in the default of the product (Loi relative à la responsabilité du fait des produits défectueux, art. 7).

6.5.2 Compensation and Insurance

Those potential defaults in the medical sector can induce important costs, which is why it is crucial to stay aware of the impact it could have on Guinevere's business. The law of March 31st, 2010 is related to the compensation due to a damage in the case of health care. The article explains deeply what can be done in such a situation (Loi relative à l'indemnisation des dommages résultant de soins de santé).

One of the four mandatory insurances that a business must have is civil liability, which covers property and physical damage that Guinevere could cause to another person. Guinevere will opt for Allianz's professional liability insurance. The latter also covers damage caused as a result of the installation of equipment. The highest cover, up to 5 million euros of protection, will be taken because damage in the medical field can have significant consequences (Allianz, 2020).

6.6 Conclusion

The main objectives of this chapter were to assess what legal form Guinevere should adopt, its advantages and drawbacks, to find out whether a patent could be considered, solutions in case of defects in the product, to analyse the different contracts that would be useful to us and to examine the human structure of Guinevere.

The choice of the legal form will allow us to be more precise in our estimations of the financial plan of the chapter 7. The feasibility of the patent reinforces the choices that have been made on the strategic level and is an asset for Guinevere both from a financial point of view and from the credibility perspective as indicated in the chapter 3.

Summary table of the legal and administrative part	
Guinevere's Human Resources	- Jean Wilberz - CEO - Bastien Nothomb - CTO - Harry Usuwiel - CFO - Tancrede d'Aspremont Lynden - CMO
Guinevere's legal identity	- Limited liability company (SRL) advantages are no minimum capital & a limited liability. - Guinevere for both the legal name and company name - "The purpose of the company is the sale and provision of a gesture recognizer as well as a computer software enabling the use of the said recognizer. " - The founders will each contribute €5000 - 400 shares with a value of €50 - Ordinary shares
Intellectual property	Conditions: 1) the patent has to be an invention 2) the novelty of the invention 3) an inventive step 4) industrial application Advantages: 1) right of prohibition 2) to put a project in the spotlight 3) credibility Disadvantages: 1) costly (time and money) 2) Be consulted by anyone 3) Limited duration
Useful contracts	- Business contracts: When providing services to hospitals - Employment contracts: Hiring employees - Sales contract: Especially when purchasing the devices from Leap motion
Liability in case of product defect	- "The producer is responsible of the damage caused by a default of the product". - "The proof of the defect, the damage and the causal link between the defect and the damage shall be incumbent on the injured party". - Compensation and insurance

CHAPTER

7

FINANCIAL PLAN

The financial plan is intended to quantify what was explained earlier in this thesis. It will be organized in six different sections: the projected turnover, the costs involved in Guinevere, the expected financial results, the performance indicators and the cash flow forecast. In order to carry out this process, certain assumptions have been made which may not fully reflect reality. The assumptions used are as follows:

- There are approximately 11 operating rooms per hospital in Belgium (AFISO, 2012). Furthermore, 104 hospitals have operating rooms in Belgium (Health Belgium, 2012).
- Average time spent in an operating room is 110 minutes (KCE, 2009). The average total cost of an operation is €10,80 per minute, of which 48% is related to salaries (KCE, 2009).
- There are 234.2 million operations per year in the world and roughly 405 000 operating rooms. Therefore, there are approximately 577 operations per operating room each year (World Health Organization, 2012).
- During the first year, the company will not commercialize its solution but will test it in UCLouvain hospitals. In addition to that, from the second year, the company will obtain an initial partnership with the UCLouvain clinics, which has 65 operating rooms (CHR, 2020; Hôpital Saint Luc, 2020).
- Hospitals pay the outstanding balance at 30 days after the end of the month. As for

the suppliers, the company pays them at 30 days after the end of the month as well.

- In terms of customer retention, as Louis-Philippe Broze explained it, switching costs in the medical sector are very high and it is very difficult to acquire new customers. However, once a customer has been acquired, he will probably stay for a long time. A retention rate of 100% was therefore taken into account in the realization of the following financial plan.
- Time saved thanks to Guinevere's solution is on average 132 seconds per operation while 22% of operations require several medical imaging consultation (GestSure, 2015). A complete cleaning of the hands and forearms that a surgeon must do to ensure sterility with the patient takes 5 minutes (World Health Organization, 2015). If the surgeon removes his or her gloves (rather than asking a nurse to assist him) twice during the operation to consult medical images, a total of 10 minutes of extra procedure could be avoided. For all the surgeries performed, we therefore arrive at more than 2 minutes saved (132 seconds exactly) for each operation performed in an operating room thanks to Guinevere's solution.
- In order to keep our treasury as stable as possible the team decided to use a monthly subscription-based model.

7.1 Projected Turnover

7.1.1 Prices

As already explained in the business model canvas, Guinevere has opted for a monthly subscription per operating room (see chapter 3.10). Pricing is a key factor in the success of Guinevere SRL as price will have an impact on both demand and profitability, but also on the positioning of the company and the competition. Three elements are necessary to set a price: demand-related prices, competitors' prices and costs related to the activity.

Price related to activity costs

Technical price

This involves adding to the monthly variable costs 7.6, the monthly fixed costs observed in the operating costs table (7.7) and dividing the sum of these costs by the number of Guinevere solutions sold each month. As specified in the assumptions, marketing will not begin before January 2022 (7). The technical price will therefore be calculated on the basis of the average of the four years following commercialization. The technical price will be €263 per month.

	2021	2022	2023	2024	2025
Fixed costs	€3 458	€139 206	€142 204	€145 202	€148 695
Variable costs	€0	€12 910	€29 970	€35 041	€40 113
Number of operating rooms	0	28	65	76	87
Technical prices per operating room per month	-	€453	€221	€198	€181

Table 7.1: Technical prices per operating room per month

Price related to competitors

Regarding competitors' prices, as mentioned above, it was unfortunately not possible to acquire the costs of each of them (3.1). Nevertheless, it can be seen from the table below that the average price of all Guinevere's competitors is €444 per month.

Competitor prices per month	
aeroTAP	€163
GestSure	€919
Tedcas	€250
Average competitor prices	€444

Table 7.2: Competitor prices per month

Demand-related price

About the price hospitals are willing to pay, it is calculated according to the costs Guinevere will save them. In fact, if a hospital has this solution, it will save approximately €6 589 per operating room each year, or €549 per operating room each month. In addition, they would be ready to pay half of what they would save with Guinevere's product which is to say €274. Therefore, our solution would save about €220, including the cost of our solution.

Money saved thanks to the solution	
Average time per operation in min	110
Average cost of an operating room per minute	€11
Personnel costs allowance (variable costs over time)	48%
Surgeon/nurse salary costs per min	€5
Average number of operations per operating room	577,71
Time saved thanks to our solution (time in minute)	2,2
Total savings with our solution/operating room/year	€6 589
Total savings from our solution/operating room/month	€549

Table 7.3: Money saved thanks to the solution

Price summary chart

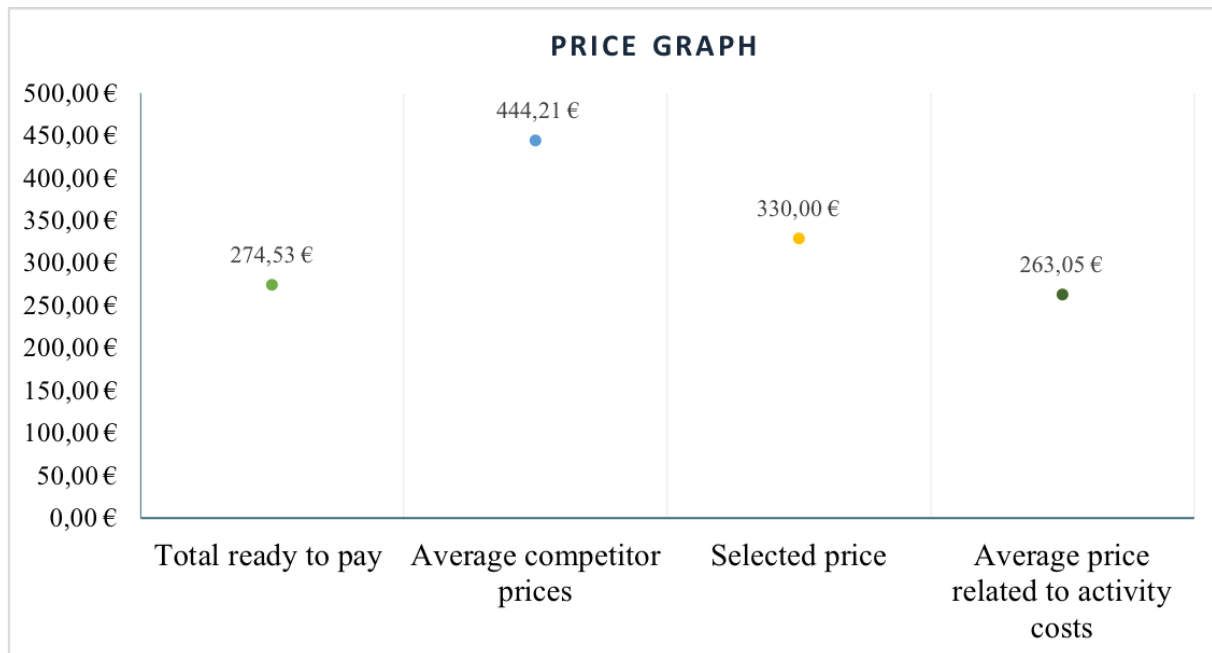


Figure 7.1: Price Chart

7.1.2 Estimation of Market Share

In order to estimate the market share, the assumption is that Guinevere SRL will have a partnership with the UCLouvain clinics and will gradually become integrated into all its hospitals, meaning 65 operating rooms, after two years of commercialization. In the first year, as explained earlier, the company will not commercialize its solution. From the second year, the company will take care of the implementation of the solution in the University clinics of St. Luc, which has 28 operating rooms. The third year will target the CHU UCL Namur, which has 37 operating rooms. Then, the company will have the heavy task of finding a new partner hospital each year, knowing that each hospital has an average of 11 operating rooms. The table below depicts this process.

Year	2021	2022	2023	2024	2025
Number of operating rooms contracted	0	28	65	76	87
Market share on the Belgium market	0%	2%	6%	7%	8%

Table 7.4: Combined market shares table

7.1.3 Turnover Projection

The turnover is calculated by the number of sales multiplied by the price. In the case of Guinevere SRL, the number of sales is cyclical given the business model and is determined

by the number of operating rooms in which the solution is implemented. The price will remain the same for at least the first four years of commercialization and will be €330 per month. The table below shows the projected turnover for the first five years of activity.

Turnover projection	2021	2022	2023	2024	2025
Price of the solution	€330	€330	€330	€330	€330
Turnover per year	€0	€110 880	€257 400	€300 960	€344 520

Table 7.5: Turnover per year table

7.2 Costs

In this section we will identify all the variable costs, fixed costs and investments required for Guinevere SRL to operate.

7.2.1 Variable Costs

The company's variable costs are closely linked to the main supplier, which is Leap Motion. The software for the Guinevere solution will be developed in-house by Bastien Nothomb. Therefore, no other costs proportional to the sales volume should be incurred.

Description	2021	2022	2023	2024	2025
Commercial license for a Leap Motion	€0	€461	€461	€461	€461
Commercial license for one Leap Motion per month	€0	€38	€38	€38	€38
Total	- €	€12 910	€29 970	€35 041	€40 113

Table 7.6: Variable costs table

7.2.2 Fixed Costs

These are all costs that do not change with the level of activity. In this section three different costs will be discussed: operating expenses, salary costs and investments.

Operating expenses

These are all fixed costs without accounting for salary costs and investments. Operating costs will be low during the first year, given that the solution will not be marketed before 2022. The most important costs will be those related to insurance, travel costs related to the implementation of the solution in the various hospitals, which can sometimes be quite far, and finally, the co-working space in Louvain-la-Neuve. All the fixed costs without the salary costs and investments can be found in the table below (7.7).

	Description	2021	2022	2023	2024	2025
Cloud hosting fees for our solution	Cloud Azure: 1 Virtual Machine 1 B2S (2 virtual processors, 4 Go RAM) x 730 Hours	€0	€416	€416	€416	€416
Customer relations and marketing	Four people accessing Zendesk CRM	€0	€294	€294	€294	€294
	Website hosting and domain name	€181	€181	€181	€181	€181
	Business cards for the 4 founders	€121	€121	€121	€121	€121
	Webite creation	€1 500				
	Graphic design	€110				
Material purchase	Purchase of four Leap Motion for tests	€358	€0	€0	€0	€0
Insurance	Allianz Professional Liability Insurance		€2 500	€2 500	€2 500	€2 500
Office	Co-working space of Louvain-La-Neuve		€12 000	€12 000	€12 000	€12 000
Telephony	Four Bizz mobile phone subscriptions (10gb, unlimited sms and unlimited calls)	€768	€768	€768	€768	€768
Commuting expenses	Commuting expenses	€0	€14 612	€14 612	€14 612	€14 612
Company detention costs	Annual company contribution	€348	€348	€348	€348	€348
	Filing fee for annual publication at the BNB	€73	€73	€73	€73	€73
Patent fees	Annual taxes					494 €
Total		€3 458	€31 275	€31 275	€31 275	€31 769

Table 7.7: Fixed costs table

Wage costs

The company does not plan to pay its managers prior to the start of commercialization in order to avoid investing too much seed capital before the solution is commercialized. This will also save the cost of the ONSS contributions. In order to still receive a "salary", each manager of the company plans to apply for the "Airbag au Forem", which is a source of financing for self-employed people in the start-up phase. Concretely, this source makes it possible to get a maximum of €12 500 over a period of two years in four installments. This source of financing will allow the managers to hold on until the first salary is paid. It should also be noted that salaries from 2022 onwards will increase by €50 net each year.

Description	2021	2022	2023	2024	2025
Gross salaries	€0	€86 400	€88 800	€91 200	€93 600
Employer contributions (ONSS)	€0	€21 531	€22 129	€22 727	€23 325
Total	€0,00	€107 931	€110 929	€113 927	€116 925

Table 7.8: Wage costs table

Investments

The investments will mainly concern the costs related to the patent and to the incorporation of the company. These costs will therefore be depreciated. The patent costs will all be depreciated over 20 years, the life of the patent, while the set-up costs will be depreciated over 5 years. The table below shows all investments and their effective dates. The table concerning the annual depreciation periods can be found in the appendices, as well as the table relating to formation expenses.

Summary table of Investments			
Date	Description	years	Amount
janv-21	Costs of setting up the company	5	€1 182
janv-21	Draft application (Patent)	20	€6 612
janv-21	First filing EP priority date	20	€1 653
janv-22	second filing PCT	20	€3 306
juin-23	Exam	20	€8 264
janv-24	Grant + Validation	20	€3 306
Total			€24 322,12

Table 7.9: Investments table

7.3 Financial Results

7.3.1 Income Statement

The income statement is an accounting document that presents all of a company's income and expenses for a given period. The table below shows that the company will only have a positive net result for the year incurred at the end of the third year.

Forecast income statement					
Description	2021	2022	2023	2024	2025
Turnover	€0	€110 880	€257 400	€300 960	€344 520
Procurement and merchandise	€0	€12 910	€29 970	€35 041	€40 113
Change in inventory	€0	€0	€0	€0	€0
Gross margin	€0	€97 970	€227 430	€265 919	€304 407
Adjusted gross margin	€0	€97 970	€227 430	€265 919	€304 407
Services and goods	€3 458	€31 275	€31 275	€31 275	€31 769
Personnel	€0	€107 931	€110 929	€113 927	€116 925
Earnings before interest, taxes, depreciation, amortization and depreciation (+/-)	-€3 458	-€41 236	€85 226	€120 716	€155 712
Amortization	€650	€815	€815	€1 393	€1 393
Operating income (+/-)	-€4 108	-€42 051	€84 411	€119 323	€154 319
Financial income (subsidies)	€0	€0	€0	€0	€0
Financial expenses (interest)	€0	€0	€0	€0	€0
Profit before tax (+/-)	-€4 108	-€42 051	€84 411	€119 323	€154 319
Taxes (+20%)	€0	€0	€0	€23 865	€30 864
Net income (+/-)	-€4 108	-€42 051	€84 411	€95 458	€123 455
(Profit/loss reported)	-€4 108	-€44 511	€39 900	€95 458	€123 455

Table 7.10: Income statement

7.3.2 Balance Sheet

Guinevere's assets will be made up of four main sources, the first of which will be the start-up costs related to the creation of the company. Secondly, intangible assets related to the patent filing process. Then, receivables with a maximum term of one year starting in 2022 when commercialization begins. Finally, the liquid assets.

ASSETS					
Description	31/12/2021	31/12/2022	31/12/2023	31/12/2024	31/12/2025
Fixed assets	€9 446	€3 306	€8 264	€3 306	€0
Start-up costs	€1 182	€0	€0	€0	€0
Intangible fixed assets	€8 264	€3 306	€8 264	€3 305	€0
Property, plant and equipment	-	-	-	-	-
Financial fixed assets	-	-	-	-	-
Current assets	€6 446	€31 800	€112 936	€199 513	€238 327
Receivables due in more than one year					
Inventory					
Receivables within one year	€0	€11 180	€25 955	€30 347	€34 739
Cash investments					
Available values	€6 446	€20 620	€86 981	€169 166	€203 588
Adjustment account					
TOTAL ASSETS	€15 892	€35 106	€121 200	€202 819	€238 327

Table 7.11: Assets table

As regards the company's liabilities, they will mainly consist of start-up capital, capital invested by a third party, losses and profits carried forward from the year incurred and short-term debts.

LIABILITIES					
Description	31/12/2021	31/12/2022	31/12/2023	31/12/2023	31/12/2023
Shareholders' equity	€15 892	€33 804	€118 178	€175 429	€203 425,49
Capital	€20 000	€80 000	€80 000	€80 000	€80 000
Share premium					
Revaluation gains					
Available reserves					
Deferred income (loss)	-€4 108	-€46 196	€38 178	€95 429	€123 425
Provisions and deferred taxes	0	0	0	€23 857	€30 856
Debts	€0,00	€1 302	€3 022	€3 533	€4 045
Long-term debts					
Short-term debts	€0	€1 302	€3 022	€3 533	€4 045
Accruals and deferred income					
TOTAL LIABILITIES	€15 892	€35 106	€121 200	€202 819	€238 327

Table 7.12: Liabilities

7.4 Performance Indicators

In this section, five performance indicators will be analyzed: Break-even point, return on equity, operating profit margin, net profit margin and operating cash flow.

7.4.1 The Break-Even Point

The break-even point is calculated as follows: $((\text{Turnover} \times \text{Fixed costs}) / (\text{Margin on variable costs}))$.

The table below indicates that the company will not be profitable in the first years of commercialization. Indeed, in order to reach the break-even point, the turnover should have been of 158 472 euros the second year, which is not the case. Nevertheless, from the second year of marketing, the company will be profitable and will remain so at least according to the forecasts until 2025. The third line of the table below informs the number of operating rooms that this company will have to reach in order to be profitable. This number is reached in Guinevere's third year of existence.

The break-even point	2021	2022	2023	2024	2025
Margin on variable costs	-€	€97 970	€227 430	€265 919	€304 407
Break-even point	-€	€158 514	€161 908	€165 955	€169 908
Number of rooms that must be reached to be profitable	-	40	41	42	38

Table 7.13: Break-even point table

7.4.2 Return on Equity

The formula for return on equity is as follows: $\text{ROE} = (\text{Net income}) / (\text{Equity})$.

It represents the return on capital raised by shareholders. The table below represents the ROE per year of Guinevere SRL. It is negative for the first three years due to the different investment, but also because the company is still in its early development stage and has few customers.

Return on equity	2021	2022	2023	2024	2025
Net income (+/-)	-€4 108	-€42 088	€84 374	€95 429	€123 425
Shareholders' equity	€15 892	€33 804	€118 178	€175 429	€203 425
Return on equity	-26%	-125%	71%	54%	61%

Table 7.14: Return on equity table

If an investor had invested in Guinevere in 2022, he would have achieved a ROE of 15%. This is extremely positive and will definitely be an argument to convince investors.

7.4.3 The Operating Margin

The operating margin is calculated as follows : $OM = (\text{Operating income})/(\text{Sales})$.

It makes it possible to determine the company's profit margin by taking into account only the company's activity, i.e. the operating result. By excluding financial and exceptional results from its calculation, the operating margin makes it possible to assess whether the enterprise itself is profitable and is not based solely on exceptional and/or financial income. The operating margin of Guinevere SRL is positive from the second year of commercialization and continues to increase until 2025.

Operating margin	2021	2022	2023	2024	2025
Guinevere's operating margin	-%	-38%	33%	40%	45%

Table 7.15: Operating margin table

7.4.4 The Net Profit Margin

The profit margin is calculated as follows: $(\text{Net income})/(\text{Sales})$ The net profit margin ratio indicates the percentage of turnover that a company retains after covering all its costs, including interest and taxes.

Since Guinevere does not pay any taxes and does not take out any bank loans, its net profit margin is the same as the operating margin in the first three years. However, from the fourth year onwards, its net profit margin ratio is different because it obtains a positive pre-tax result and ultimately pays taxes.

Net profit margin	2021	2022	2023	2024	2025
Guinevere's net profit margin	-%	-38%	33%	32%	36%

Table 7.16: Net profit margin table

7.4.5 Operating Cash Flow

Cash flow from operating activities is calculated as follows: $\text{Net income} + \text{depreciation} + \text{write-downs} + \text{provisions}$.

It allows to analyze the self-financing capacity of a company. As the table below shows, from the third year onwards the operating cash flow is positive. It will allow the company either to repay its debts or to hoard.

Operating cash flow	2021	2022	2023	2024	2025
Net income	-€4 108	-€42 088	€84 374	€95 429	€123 425
Depreciation	€650	€815	€815	€1 393	€1 393
Operating cash flow	-€3 458	-€41 273	€85 189	€96 822	€124 819

Table 7.17: Operating cash flow table

7.5 Cash Flow Statement Projections

The graph below illustrates the cash flow when no capital is contributed. In addition, it is important that the balance at the beginning of the month is not negative. Therefore, this graph shows the financing needs of the company Guinevere SRL which is €68 208 but in order to reduce the risk of a negative balance, the company will raise €80 000.

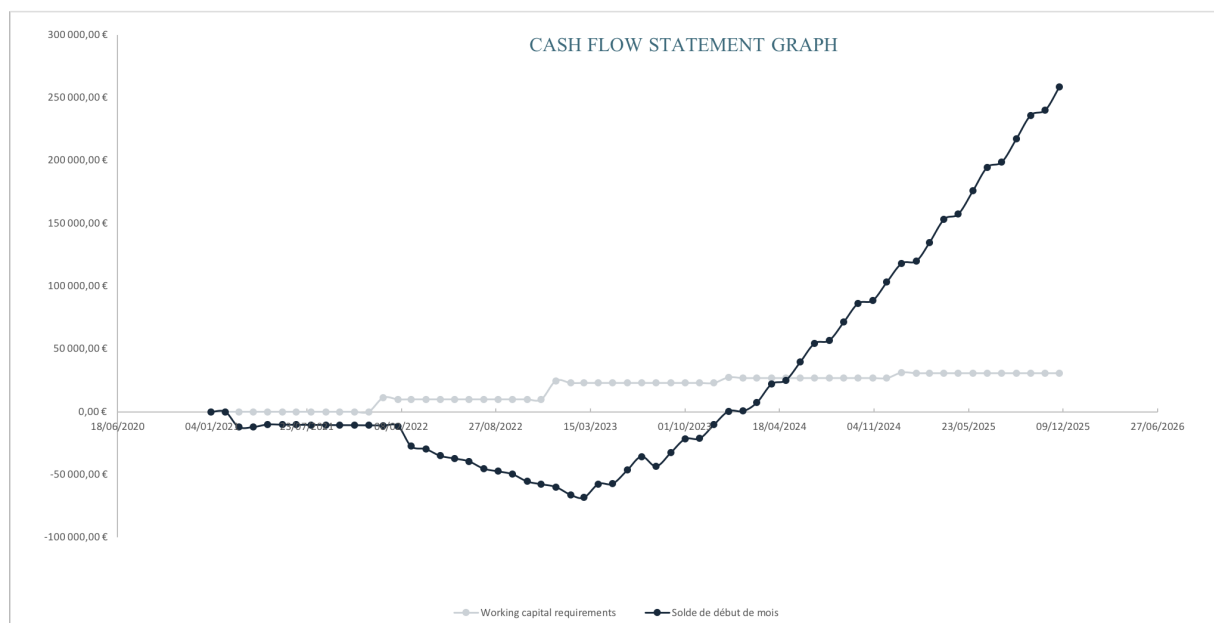


Figure 7.2: Cash flow statement before injections

This graph depicts the working capital requirement, which is the amount that a company must finance in order to cover the cash flow gap between expenses and revenues. In the case of Guinevere SRL, the working capital requirement remains positive because the time lag between suppliers and customers is the same. Nevertheless, this could be different in reality.

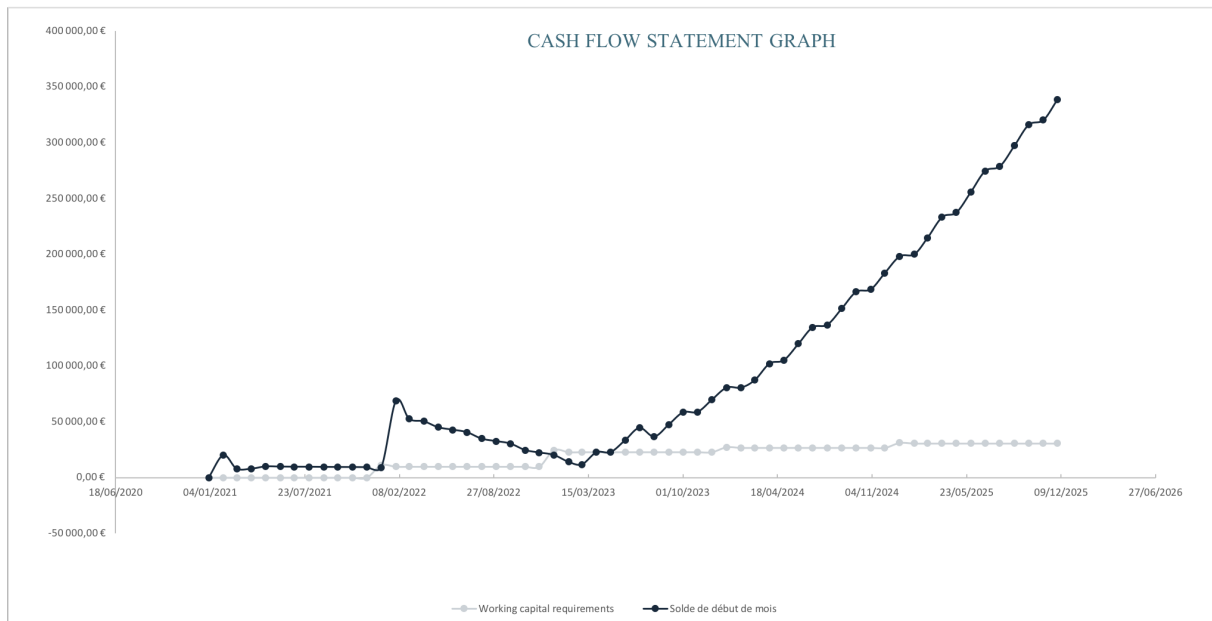


Figure 7.3: Cash flow statement after injections

The second graph shows the cash flow after capital injections. It shows that the balance at the beginning of the month remains positive, which is necessary for the good functioning of the company, which implies that the total sum invested seems to be the right one. This financing will be carried out in two phases. The first one is the launch of the company during which the first steps of the patent application will have to be carried out, as well as the costs of setting up the company. In this first stage, the directors and founders of the company will invest €20 000. The second phase corresponds to the commercialization phase of the solution. This phase will take place after the validation of the various tests in operating rooms. The managers and founders of the company will seek funding of €60 000 to finance the final stages related to the patent application, as well as the costs caused by the company's activity.

7.6 Funding Sources

7.6.1 Self-Financing

Section 6 of the cash flow plan shows the required capital injections. As the first year is aimed at the development of the Guinevere solution and the founders do not receive a salary based on the company's resources, the cash burn rate remains relatively low. The financial needs amount to just above €12 000. These will be covered by a total contribution of €20 000 in self-financing, contributed equally by each of the founders, i.e. €5000 per person. The difference of €8000 is intended to avoid running out of cash.

7.6.2 Business Angels

After the first year, if the research proves to be conclusive, it will be necessary to look for new capital. This time, the sum amounts to €60 000. This amount falls well within the spectrum of business angels who invest between €15 000 and €500 000 in early stage European entrepreneurial projects (Janssen, 2016). The advantage of this type of partner lies not only in the capital contribution but also in its experience. Most of them are successful entrepreneurs and wish to remain active by participating in other projects. They also tend to specialize by sector, and this is where the BA would be particularly useful to the Guinevere team, which does not have this type of profile.

Whereas before the medical field remained in close contact with the biggest industries, the trend has been reversed thanks to the development of new technologies such as 3D printing, IoT, virtual and augmented reality or big data, but above all by the strong growth of startups all over Europe (Liénart, 2017). France seems to offer interesting opportunities in terms of medical startup financing. Doctolib has raised funds in series C and D for a total of 61 million euros, BioSerenity 15 million euros in series B and there are many other examples (Angelsquare, 2018).

7.6.3 SOPARTEC and the VIVES Fund

Since the Guinevere company intends to become a spin-off from UCLouvain, the €60 000 investment could be requested from SOPARTEC, which manages a fund called VIVES. The latter is "a seed capital fund initiated by UCLouvain which invests in companies developing breakthrough innovations with a positive societal impact" (VIVES, 2020). The fund is in the process of creating its third VIVES Inter University Fund (VIVES IUF) and the first round of financing should be completed shortly (VIVES, 2020). This fund therefore seems difficult to reach for the company given its immature state but could be relevant for Guinevere's future.

7.7 Conclusion

The main objective of this chapter was to provide a simulation of Guinevere's financial forecasts, which confirmed the opportunity that this company could represent from a financial point of view. It also allowed to assess the financial needs that Guinevere will require at its launch and the financing options available.

The insights provided by this chapter will mainly serve to meet one of the objectives mentioned in the section 1 of this thesis, namely "to define whether such an implementation could be profitable from a financial point of view". Secondly, the risks of this chapter will be analysed in the chapter 8 that will allow us to prepare ourselves in case our forecasts

do not match reality.

Financial forecasts					
	2021	2022	2023	2024	2025
Combined market shares	0%	2%	6%	7%	8%
Turnover	-€	€110 880	€257 400	€300 960	€344 520
Net income (+/-)	- €4 108	- €42 088	€84 374	€95 429	€123 425
Break-even point	- €	€158 514	€161 908	€165 955	€169 908
Return on investment	-26%	-125%	71%	54%	61%

CHAPTER

8

RISK MANAGEMENT

The development of a solution in the technological and medical environment involves many risks and uncertainties about the future of the company. This is why it is crucial to identify most of these risks today so solutions can be elaborated to counter them.

In the first section of this chapter, risks will be identified at a large perspective. They are related to the integration of this complex medical-world market. The second section presents a short risk analysis based on the Financial Plan presented in chapter 7. The third section is a presentation around the risks involved in the development of Guinevere's software and its interoperability with different kinds of hardware. Direct and far reaching consequences can be seen if the solution were to default. The final section is related to the third one as it will treat the legal consequences in terms of default of the solution and ways to ensure legal protection for Guinevere. A quick review of the risks and limits of the patent will also be given.

8.1 Risks related to the Medical Market

Following the webinar on medical entrepreneurship hosted by UStart (referenced in the appendix E.0.1), the actors Tooddoc and Spentys testified the difficulty of accessing the hospital market. The latter is filled with numerous administrative procedures and requires a meeting of all decision makers before moving to a higher level. In addition to that, the switching cost of medical equipment is very high. These points highlight the barriers to

market entry.

8.1.1 Partnerships

Many of our hypotheses depend on the partnership with the UCLouvain hospitals. In the table 3.1 regarding the competitive environment of Guinevere’s market, all of the existing competitors had at least a partnership with one hospital. In terms of credibility, having such a partnership is therefore crucial for Guinevere to be able to approach new customers. The latter need to have the certainty that the product is working and has made its proofs.

Furthermore, for other customers than the UCLouvain, it will be necessary to get to know their working environment and especially to learn about the machines they use to display their medical images. Indeed, each hospital can choose to work with the DICOMs of its choice and this is the reason that can make a medical environment different from another. It will be essential to connect Guinevere’s software to the DICOM used by the hospital.

Finally, it is crucial to mention that the process of research and development around Guinevere’s solution is not over yet. The latter is planned to continue its modeling in the operating rooms of the UCLouvain during the two first years of the business plan, the testing and finally to go “live” on the market. The partnership with the UCLouvain will be crucial to test every risk that the solution may lead to.

8.1.2 Direct Competition

As mentioned in the Porter analysis (3.5), the market for gesture recognition in the hospital sector is unfilled in Belgium and only a few players share the market on the international scene. However, before 2014, a tremendous actor was doing researches on the subject, namely Microsoft. According to Gerardo Gonzalez, former Microsoft researcher, the project stopped after two years. However, he stated that “*Back then surgeons wanted a commercial product developed by Microsoft to use in hospitals*”, so a question that rose was: why would Microsoft not enter the market? Could it have something to do with the fact that this application is too risky? Or are they just working on more efficient technologies?

What is sure is the fact that if they had to enter the market, the product developed internally would be more appealing to surgeons, thanks to the reputation of Microsoft’s trademark.

8.1.3 Indirect Competition

A few lines earlier, it was mentioned that Microsoft could be working on a more efficient technology. This is indeed what they have done in 2018 with their researches on the

HoloLens in surgery. The sensors and gesture recognition algorithms are inspired from the ones of the Kinect. The integration of the HoloLens in the operating room might be a better solution than Guinevere's. However, in terms of pricing and usability, Guinevere is still ahead of the medical images display with the HoloLens. Nonetheless, the situation could still evolve and become a bigger threat over time.

8.2 Financial Risks

8.2.1 Decreasing Healthcare Budgets and Influence of the Covid-19 Crisis

In the PESTEL analysis in section 3.3, we have identified the decrease in growth in the healthcare budget. However, while writing this thesis, the Covid-19 emerged. Potential future consequences related to this pandemic should be taken into consideration. Even though Belgium is considered as one of the best countries in terms of the quality of healthcare, the actual distress in hospitals proves that being one of the best is not enough (L'Echo, 2019). Politics could reconsider the budget and increase the current 10% of the GDP invested in healthcare.

The PESTEL analysis also mentioned a heavy conservatism within the hospital sector. The crisis may trigger a shift in this respect. For instance, the Saint-Pierre CHU director shared in the newspaper *Le Soir* nine lines of thought to think after the crisis. In the case of the project Guinevere, the 8th is particularly interesting as it claims that the government should increase its support to the Belgian health-tech ecosystem. Many innovative projects have been helping out hospitals in a short period of time. He finished his paragraph by stating: "*These initiatives have often fallen foul of an outdated regulatory environment. Let's learn from them quickly. This ecosystem will stimulate the urgently needed transformation of the model*" (Leroy, 2020). While this statement stays at the medical level, it might influence Belgian leaders to take actions in this domain. This request also testifies the openness of the medical sector to innovate and change the slow bureaucratic medical environment.

At the European level, some announcements were done concerning investment funds to tackle the crisis. Namely, on May 12th, an investment of €72 million has been unlocked by the Innovative Medicines Initiative (2020) where 20% were attributed to SME's. Within those projects, some intent to *combine expertise in clinical epidemiology with digital devices (such as **wearables** and mobile apps) to rapidly and reliably detect cases so that they can be prioritized for testing* (Innovative Medicines Initiative, 2020). This confirms the utility and future presence that wearable technologies will have during and after the crisis.

8.2.2 Neglected Forecasts of Costs and Revenues

The forecasts done in the financial analysis may have neglected some costs. For instance, the gesture recognition algorithm cost developed by Professor Vanderdonckt and his team does not figure in the expenses. As the latter had many years of research for its development, a compensation should be given in a certain type of way: pecuniary, company shares or material. Another example of costs that may have been seen lightly is the €50 monthly salary augmentation after each year. A low income can be acceptable at the beginning of the creation of a company but after some years, people are willing to receive more for their contributions. Some other costs may have. In term of revenues, the price is set at €330 per month per operating room. Some customers may be willing to negotiate the price if they take our solution for many operating rooms. Many other eventualities may happen that the financial plan has not taken into account. This is why, in the treasury forecasts, there is always a certain cash reserve to prevent any financial eventuality.

8.2.3 Investment

Guinevere's financing needs remain relatively moderate, but external sources are still necessary. The choice to call upon a business angel will lead to a dilution of the shares. This dilution will depend on the valuation of Guinevere SRL. In many cases, entrepreneurs tend to overvalue their business and, on the contrary, investors tend to moderate this valuation in order to increase their shares' amount in the capital.

8.2.4 Bankruptcy

Guinevere's activity is not very demanding in terms of financial resources. In order to avoid a cessation of payments due to a lack of cash reserves, the decision to raise slightly more funds than necessary was taken. In the book "Entreprendre, an introduction to entrepreneurship", we can read that in most countries, cessation of payments is considered as a source of bankruptcy and therefore, as a consequence, of entrepreneurial failure (Janssen, 2016). But the spectrum of failure remains broader, a voluntary interruption of activity without cessation of payment remains in European mentalities, an entrepreneurial failure assimilated to the so-called mismanagement of managers. Yet it often remains beyond the control of managers, exogenous elements such as the current crisis following the COVID-19 pandemic can happen.

As a financial consequence of the failure of the Guinevere project, the four founders could lose the €20 000 of capital invested. Also, the business angel could lose up to €40 000. In addition, the reputation of the founders, in a European environment, could be affected on the entrepreneurial scene.

8.2.5 Product Default

The major risk that comes to mind is the failure of the solution during an intervention in the operating room. This may be due to a software update or other technical reasons. If the surgeon is not able to have access to medical data during the operation, it could lead to medical consequences implying the founder's responsibility from minor issues to the worst-case scenario, being the patient's death.

Alternatives in case of the defect of the product are therefore crucial. Moving to a more traditional way of navigating with medical data must be easy in case of Guinevere's product default.

As this requirement could be a deal-breaker, it seems important to offer a guarantee to the customer that the chances of a default are very thin. If it occurs during an operation, a financial collateral or a price deduction could be used as a marketing tool to convince the customer and enhance his confidence in Guinevere's solution.

8.3 Legal Protection

The following section gives an idea of the legal repercussions Guinevere could face in its business activities in case of its solution's default. This section covers how to tackle these issues thanks to the insurance and the condition of usage that can be used as a legal protection.

8.3.1 Insurances

Being able to assess the responsibility of the company in various scenarios is a way to reduce the risks faced by the mentioned company. Insurance brokers are the links between insurances companies and businesses to help and advise entrepreneurs. In the case of Guinevere, the links were done with AAA Capitalassur to receive this support. Professional liability insurance ("RC Exploitation et après Livraison") allows to intervene in the context of several risks that have been mentioned in the section related to the defect of Guinevere's product. The insurance offered by AG Insurance allows to cover the company's liability during the service but also afterwards, should a defect appear later in the case of a bad installation (AXA, 2020).

Depending on the annual premium, proportional coverage is provided for body injury, property damage and consequential loss or damage to property that could have been caused by one of Guinevere's interventions. This can be applied during the execution of Guinevere's services but also after installation.

It is important to mention that these insurances obviously only cover damage under

certain conditions.

8.3.2 User's Guide and Warranty

These two documents will be presented during training sessions for surgeons to make them aware of the correct use, the different possibilities and limitations of the medical imaging navigation system. The user guide and the warranty will have to be written progressively during the various tests in the operating rooms of UCLouvain in order to cover all the points that may be able to limit Guinevere's liability.

8.3.3 Patent

In the legal analysis, the pros and cons have been discussed around the decision to start the procedures of a patent filing (6.3.2). These prove to be long in terms of time and cost, with a price of €24 000. At the beginning of Guinevere's activity, treasury will have important monetary needs and it does not plan to bring any financial income through the sale of licences.

The question therefore arises whether protecting this competitive advantage will benefit us or, on the contrary, will it harm us in terms of the inefficient allocation of our efforts?

8.4 Conclusion

Setting up a business entails risks at various levels. Being able to identify them in advance allows to put in place mechanisms to mitigate or even eliminate these risks. The table below highlights the risks that seemed most critical to the Guinevere team.

Summary Table of the Risk Management Part	
Medical Market	Market entry barrier due to the high switching costs and bureaucratic organization
Partnerships	Obligatory to enter the market
Direct Competition	Possible entry of company like Microsoft
Indirect Competition	Fast evolution of the technology making a previous one potentially obsolete
Financial Risks	Moderate risk of capital dilution
Legal Protection	Case of product defect that could impact the patient health
Insurances	Legal coverage under strict conditions
User's Guide and Warranty	Possible limitation of Guinevere responsibility
Patent	Long and costly

CHAPTER

9

THESIS CONCLUSION

Throughout this report, the solution proposed by Guinevere, which aims to facilitate the navigation of medical data in the operating room, was analyzed from strategic to financial, including technical, communication and legal aspects. At this stage, this allows us to answer the questions raised in the introduction.

The **first question** was whether there was a business opportunity behind this project or not. Chapter 4 of Janssen (2016) allows us to answer in the affirmative. Indeed, as it states, "*an opportunity is an idea that creates value for the entrepreneur*" and the financial part of this business plan confirms there is value for the four founders of Guinevere. The presence of market players such as TedCas, aeroTAP or STS Progesoftware is an additional element reflecting that there is an interest in this market. Even though a number of them seem to have given up along the way.

As it seems there is no official record of the reasons of interruption of these projects. Our group first hypothesized that the sudden halt in the commercializing of the Kinect by Microsoft had played a destabilizing role for the startups in this market. Indeed, in our analysis of the competition, all the players started by using the Kinect sensor in their solutions, which induced a high bargaining power of the sensor supplier. At the time of Microsoft's announcement, some companies were perhaps already in a difficult situation and this event would have been the final blow.

After questioning the CEO of TedCas, he told us that in his opinion, these failures

were caused by three reasons. The first being that their solutions were not sufficiently well adapted to the needs of surgeons, the second being related to the difficulty of the medical sector and the last one being related to the experience and user interface of the solution. These different difficulties had each been identified before our exchanges with this actor. The causes of failure of the former actors seem to us avoidable and do not present an impossibility to undertake in this environment (Pérez-Llano, 2020).

In the meantime, the recent Covid-19 pandemic occurred and has affected the market as a whole, the extent of its consequences cannot be assessed at this time. However, it has had a direct impact on our health care systems and these are being questioned. In addition to its claims regarding the budget allocated to it, part of the medical sector is also demanding to facilitate the access to start-ups in this outdated bureaucratic environment. Prior to the crisis, it had been pointed out that the Belgian healthcare budget would decrease and that conservatism was our biggest challenge. With the crisis, what we had identified as a major threat to our market could turn into an opportunity. When we attended a webinar with a distributor of our competitor TedCas, this was particularly true as their solution is increasingly being adapted as a way to combat the crisis.

According to Janssen (2016), there are seven factors that determine the opening or closing of an opportunity and we have identified three in the market in question. The competitive context is experiencing a low concentration of players on the market following the end of the Kinect, leading to the disappearance of certain players. European demographic trends predict an ageing population and will therefore result in more surgical interventions in the future. And eventually, the unexpected and negative event of the global pandemic also presents an opportunity as the entire society has its attention on the medical world. Penn Zalesne (in Janssen, 2016) mentioned that the opening of an opportunity is variable. In the case of the Covid-19, as this latter has had impacts on every aspects of the society, it will have an impact for many years.

The **second question** looked at how the technology would be developed and then implemented in the operating rooms. The issue that Guinevere addresses has the advantage of having been covered by the scientific literature in many facets. Both on the framework and on the development of the solution itself. At the development level, the framework and the DICOM viewer part have been worked on. The first one had to be developed in order to be added to the sensor used, the Leap Motion, in order to ensure the proper functioning of our solution. In addition, the framework has an objective on the longer term of Guinevere's stage of existence. It will allow to use the gesture recognition algorithm for other market applications.

Based on the functional and technical surgeons' requirements related to the DICOM's navigation, the team's engineer, Bastien Nothomb, has developed a first prototype that

has a gesture set of 14 commands and that has a theoretical recognition rate of 85%. The latter will continue to be developed during the first year of Guinevere's existence to offer the best value to the surgeons. A particular attention will be given to UX, as developed in chapter 2 and as TedCas CEO told us that it had a crucial importance on the sales success.

The **third question** in the introduction was focused on discovering the viability of this company and the financial performance it could potentially achieve. The first question proved the opportunity behind this business, it is now interesting to look at the viability of such a project and moreover, how profitable it could be.

According to the estimates made in the financial section, Guinevere could generate a turnover of approximately €110 000 in the second year and just over €340 000,00 in the fifth year, representing a ROE of -1.25 and 0.61 respectively. The company will not break even until the third year of its existence but will generate significant profits thereafter. As an example, the year 2025 should generate a profit of around €125 000.

In terms of human resources, the first five years would not require the initial four founders to hire additional people. The most important costs generated by this activity are mainly related to salaries and the cost of patent filing. In the first year of operation, we will not generate any revenue, which will result in a negative cash flow. This is why it will be necessary to raise funds from investors (ideally from business angels with expertise in the medical field) at an amount of €60 000 at the beginning of the second year of activity.

To achieve these projections, Guinevere will need to be able to capture 2% of the Belgian market in the second year and 8% in the fifth year. Guinevere's customers will have to be priced monthly at €330. We believe these estimates are achievable as our solution enables hospitals to save approximately €220 per month through the implementation of our technology, which presents an opportunity for these parties to reduce their costs.

The **fourth question** and objective lays in the creation of the legal entity and how this latter will communicate. The SRL was chosen for its low capital requirement and the creation of a moral person. The legal procedures to file a patent have been analyzed.

Apart from creating a company on a legal standpoint, namely setting up a spin-off following the identification of a business opportunity and the encouraging signals coming from the financial plan presented earlier, it would also be necessary to position the company for it to be recognizable. Based on the making of a brand platform, composed of a mission, a vision, and values, as well as an analysis of how Guinevere's competitors were positioning themselves on the market, we were able to create a brand identity specific to Guinevere.

Following the listing of the project's stakeholders, we defined how Guinevere's target

audiences should perceive its brand: as an innovative company, Guinevere facilitates the way surgeons can perform their mission, thanks to touchless technology. We want Guinevere to be perceived as a partner on which surgeons can rely and to be considered as a leading actor on the touchless market.

Nevertheless, several limitations related to this Master thesis need to be taken into consideration. One is that we were not able to test our prototype with surgeons in order to get feedback on their requirements. Indeed, exchanges with surgeons were limited due to the health crisis linked to Covid-19. Secondly, this paper had to be based on several hypotheses and if these proved to be false, this could have misled the rest of the reasoning. In particular on the reasons for the failure of market competition factors. Finally, we remain well aware that this sector remains very technical and that before taking the decision to launch an entrepreneurial project in this field, it would be necessary to surround ourselves with experts in order to benefit from their experience and support.

And **the final word** is whether Guinevere's four entrepreneurs will make the decision to take advantage of this opportunity and engage in its creation process. The Guinevere team has different ambitions for the future. Indeed, the four project leaders are going to start their professional careers in other companies in order to acquire the experience they lack and perhaps one day launch their own project.

We will therefore conclude this master thesis by reiterating, one last time, that the market for gesture recognition in the hospital sector represents both a business opportunity and a real positive contribution to society.

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APPENDIX

A

CODE OF THE SOFTWARE

A.1 Framework

A.1.1 index.js

```
1 const WebSocket = require('ws');
2 const http = require('http');
3 const config = require('./config');
4 const FrameProcessor = require('./framework/frame-processor')
  .FrameProcessor;
5
6 // Load the modules
7 const Sensor = config.sensor.module;
8
9 // Main function
10 function run() {
11     // Initialize the sensor interface, dataset, recognizer
12     // and segmenter
13     var sensor = new Sensor(config.sensor.options);
14     var frameProcessor = new FrameProcessor(config);
15     // Start the websocket server
```



```

15     var wsServer = getWebSocketServer(config.server.ip,
16         config.server.port);
17     wsServer.on('connection', async function connection(ws) {
18         console.log('Connected!')
19         frameProcessor.resetContext();
20         // Handle messages from the client
21         ws.on('message', function(message) {
22             var data = JSON.parse(message);
23             if (data.hasOwnProperty('addPose')) {
24                 let poseName = data.addPose;
25                 frameProcessor.enablePose(poseName);
26             } else if (data.hasOwnProperty('addGesture')) {
27                 let gestureName = data.addGesture;
28                 frameProcessor.enableGesture(gestureName);
29             } else if (data.hasOwnProperty('removePose')) {
30                 let poseName = data.removePose;
31                 frameProcessor.disablePose(poseName);
32             } else if (data.hasOwnProperty('removeGesture')) {
33                 let gestureName = data.removeGesture;
34                 frameProcessor.disableGesture(gestureName);
35             }
36         });
37         // Process sensor frames
38         sensor.loop((frame, appData) => {
39             if (appData && config.general.sendContinuousData)
40             {
41                 // If there is continuous data to send to the
42                 // application
43                 let message = { frame: appData };
44                 ws.send(JSON.stringify(message));
45             }
46             // Gesture recognition
47             var ret = frameProcessor.processFrame(frame);
48             if (ret) {
49                 // If there is gesture data to send to the
50                 // application
51                 let message = { gesture: ret };
52                 if (config.general.debug) {

```

```

49         console.log(JSON.stringify(message));
50     }
51     ws.send(JSON.stringify(message));
52 }
53 });
54 // Stop processing frames after disconnection
55 ws.on('close', function() {
56     console.log("Disconnected!")
57     sensor.stop();
58 });
59 // Stop processing frames after connection error
60 ws.on('error', function(error) {
61     console.log(JSON.stringify(error));
62     sensor.stop();
63 });
64 });
65 }
66
67 function getWebSocketServer(ip, port) {
68     // Create HTTP server
69     var server = http.createServer();
70     server.listen(port, ip, function () {
71         console.log("WebSocket server listening on port " +
72             port);
73     });
74
75     // Create WebSocket server
76     var wsServer = new WebSocket.Server({ server });
77
78     return wsServer;
79 }
80 if (require.main === module) {
81     run();
82 }

```

A.1.2 config.js

```

1 // MODULES
  -----

2 // Sensor Interfaces
3 //const LeapSensor = require('./implementation/sensors/
  LeapSensor').LeapSensor;
4 const LeapSensor = require('./implementation/sensors/leap-
  sensor').Sensor;
5
6 // Gesture Datasets loader
7 const UnifiedDatasetLoader = require('./framework/datasets/
  UnifiedDatasetLoader');
8 // const LeapMotionDatasetLoader = require('./implementation/
  datasets/LeapmotionConverter');
9 // const SmartphoneDatasetLoader = require('./implementation/
  datasets/SmartphoneConverter');
10 // const HandGestureDatasetLoader = require('./implementation
  /datasets/HandGestureCsv');
11 // const UWaveDatasetLoader = require('./implementation/
  datasets/uWaveConverter');
12
13 // Classifiers
14 const GPSDClassifier = require('./implementation/classifiers/
  gpsd-classifier/classifier').Classifier;
15 const NoClassifier = require('./implementation/classifiers/
  placeholder-classifier/classifier').Classifier;
16
17 // Static Gesture Analyzers
18 const BasicStaticAnalyzer = require('./implementation/static-
  analyzer/basic-analyzer/static-analyzer').StaticAnalyzer;
19
20 // Gesture Segmenters
21 const WindowSegmenter = require('./implementation/segmenter/
  window-segmenter').Segmenter;
22 const ZoningSegmenter = require('./implementation/segmenter/
  zoning-segmenter').Segmenter;
23 const LeftHandSegmenter = require('./implementation/segmenter
  /lefthand-segmenter').Segmenter;

```

```

24 const FrameSegmenter = require('./implementation/segmenter/
    frame-segmenter').Segmenter;
25
26 // Gesture Recognizers
27 //3D
28 const HybridP3DollarPlusXRecognizer = require('./
    implementation/recognizers/hybridp3dollarplusx-recognizer/
    recognizer').Recognizer;
29 const JackknifeRecognizer = require('./implementation/
    recognizers/jackknife-recognizer/recognizer').Recognizer;
30 const P3DollarPlusXRecognizer = require('./implementation/
    recognizers/p3dollarplusx-recognizer/recognizer').
    Recognizer;
31 const UVPRecognizer = require('./implementation/recognizers/
    uvplus-flexible-cloud/recognizer').Recognizer;
32 const ThreeCentRecognizer = require('./implementation/
    recognizers/threecent-recognizer/recognizer').Recognizer;
33 const P3DollarPlusRecognizer = require('./implementation/
    recognizers/p3dollarplus-recognizer/recognizer').
    Recognizer;
34 //2D
35 const PDollarPlusRecognizer = require('./implementation/
    recognizers/pdollarplus/recognizer').Recognizer;
36
37
38 // CONFIG INIT
    -----

39 var config = {};
40 config.general = {};
41 config.server = {};
42 config.sensor = {};
43 config.sensor.options = {};
44 config.classifier = {};
45 config.classifier.options = {};
46 config.staticAnalyzer = {};
47 config.staticAnalyzer.options = {};
48 config.dataset = {};
49 config.dataset.options = {};

```

```

50 config.segmenter = {};
51 config.segmenter.options = {};
52 config.recognizer = {};
53 config.recognizer.options = {};
54
55 // CONFIGURATION
    -----

56 // General Configuration
57 config.general.reportGesturesFromClient = false;    //
    Report recognized gestures only if they are requested by
    the client
58 config.general.loadGesturesFromClient = false;    // Load
    gestures based on requests from the client (requires
    detectGesturesFromClient = true to have an effect)
59 config.general.sendContinuousData = true;
60 config.general.debug = true;
61
62 // Server
63 config.server.ip = '127.0.0.1';                    // IP of the server
    (for app interface)
64 config.server.port = 6442;                          // Port of the server
    (for app interface)
65
66 // Sensor Interface
67 config.sensor.module = LeapSensor;
68 config.sensor.options.framerate = 60;              // Sensor
    framerate [seconds]
69
70 // Classifier
71 config.classifier.module = NoClassifier;
72 //config.classifier.options;
73
74 // Static Gesture Analyzer
75 config.staticAnalyzer.module = BasicStaticAnalyzer;
76 //config.staticAnalyzer.options =
77
78 // Gesture Dataset
79 config.dataset.module = UnifiedDatasetLoader;

```

```

80 config.dataset.options.directory = "./datasets";
81 config.dataset.options.name = "guinevere_unified";
82
83
84 // Gesture Segmenter
85 config.segmenter.module = ZoningSegmenter;
86 config.segmenter.options.minSegmentLength = 10;    // Minimum
    length of a segment (if applicable) [#frames]
87 config.segmenter.options.maxSegmentLength = 60;    // Maximum
    length of a segment (if applicable) [#frames]
88 config.segmenter.options.windowWidth = 20;        // Width of
    the window (if applicable) [#frames]
89 config.segmenter.options.intervallLength = 3;      // Length of
    the interval between 2 consecutive segments (if applicable
    ) [#frames]
90 config.segmenter.options.pauseLength = 60;        // Length of
    the pause after a gesture has been detected (if applicable
    ) [#frames]
91 config.segmenter.options.xBound = 120;            // 1/2 width of
    the zone (if applicable) [mm]
92 config.segmenter.options.zBound = 60;            // 1/2 depth of
    the zone (if applicable) [mm]
93
94 // Gesture Recognizer
95 config.recognizer.module = JackknifeRecognizer;
96 config.recognizer.options.samplingPoints = 16;    // Number
    of sampling points [#points]
97 config.recognizer.options.articulations = ["
    rightThumbPosition", "rightIndexPosition", "
    rightMiddlePosition", "rightRingPosition", "
    rightPinkyPosition", "leftThumbPosition", "
    leftIndexPosition", "leftMiddlePosition", "
    leftRingPosition", "leftPinkyPosition", "righthPalmPosition
    ", "leftPalmPosition"];
98
99
100
101 module.exports = config;

```

A.1.3 benchmark.js

```
1 const config = require('./benchmarkConfig');
2
3 let PrintResults = function(results, recognizer, dataset) {
4     console.log("#### " + recognizer + " #### number of
5         repetition: " + R + ", N: " + N);
6     console.log("#### gesture set " + dataset.name + " #### "
7         + JSON.stringify(Array.from(dataset.getGestureClasses
8             ().keys())));
9     for(let i=0 ; i<results[0].length && i<results[1].length
10         ; i++) {
11         console.log("Recognition accuracy with " + (i+ MINT)
12             + " training templates per gesture: " + (results
13                 [0][i]*100).toFixed(2) + " (" + results[1][i].
14                 toFixed(2) + "ms)");
15         console.log("Confusion matrice: " + JSON.stringify(
16             results[2][i]));
17     }
18     console.log("-----")
19 };
20
21 let StartTesting = function(dataset, Recognizer,
22     recognizerConfig) {
23     //console.log(dataset);
24     let recognition_rates = [];
25     let execution_time = [];
26     let confusion_matrices = [];
27
28     for(let tg= MINT ; tg < Math.min(dataset.getMinTemplate()
29         , MAXT) ; tg++) { //for each training set size
30         let current_recognition_score = 0;
31         let current_execution_time = 0.0;
32         let current_confusion_matrice = new Array(dataset.G).
33             fill(0).map(() => new Array(dataset.G).fill(0));
34
35         for(let r=0 ; r<R ; r++) { //repeat R time
36             let recognizer = new Recognizer(recognizerConfig)
37                 ;
38         }
39     }
40 }
```

```

27     let candidates = SelectCandidates(dataset);
28     let training_templates = [];
29     candidates.forEach(val =>{
30         training_templates.push([val]);
31     });
32     for(let t=0 ; t<tg ; t++) { //add tg strokeData
        per gestureClass
33         let index = 0;
34         dataset.getGestureClasses().forEach((gesture,
            key, self) => {
35             let training = -1;
36             while(training==-1 || training_templates[
                index].includes(training)) training =
                GetRandomNumber(0, gesture.getSample()
                    .length);
37             training_templates[index].push(training);
38             recognizer.addGesture(gesture.name,
                gesture.getSample()[training]);
39             index++;
40         });
41     }
42     // Recognition after tg training templates
43     let c = 0;
44     dataset.getGestureClasses().forEach((gesture, key
        , self) => {
45         let toBeTested = gesture.getSample()[
            candidates[c]];
46         let result = recognizer.recognize(toBeTested)
            ;
47         if(dataset.getGestureClasses().has(result.
            name))
48         {
49             let result_index = dataset.
                getGestureClasses().get(result.name).
                index;
50             current_confusion_matrice[result_index][
                gesture.index] += 1;
51         }

```



```

52         current_recognition_score += (result.name===
53             gesture.name) ? 1 : 0;
54         current_execution_time += result.time;
55         c++;
56     });
57     }
58     recognition_rates.push(current_recognition_score);
59     execution_time.push(current_execution_time);
60     confusion_matrices.push(current_confusion_matrice);
61 }
62 for(let i=0 ; i<recognition_rates.length ; i++) {
63     recognition_rates[i] = recognition_rates[i]/(R *
64         dataset.G);
65     execution_time[i] = execution_time[i]/(R * dataset.G)
66     ;
67     // confusion_matrices[i].forEach(function(row, x,
68         theArray) {
69         //     row.forEach(function(col, y) {
70         //         theArray[x][y] = col/100;
71         //     });
72         // });
73 }
74 return [recognition_rates, execution_time,
75     confusion_matrices];
76 };
77
78 /**
79  * choose one candidate per gesture
80  */
81 let SelectCandidates = function(dataset) {
82     let candidates = [];
83     dataset.getGestureClasses().forEach((value, key, self) =>
84         {
85             candidates.push(GetRandomNumber(0, value.getSample().
86                 length));
87         });
88     return candidates;
89 };
90

```

```

84 let GetRandomNumber = function(min, max) {
85     min = Math.ceil(min);
86     max = Math.floor(max);
87     return Math.floor(Math.random()*(max - min))+min;
88 };
89
90 let test = function(datasetName, DatasetLoader,
    GestureRecognizer, GestureRecognizerConfig){
91     let dataset = DatasetLoader.loadDataset(datasetName,
        config.datasetFolder);
92     let result = StartTesting(dataset, GestureRecognizer,
        GestureRecognizerConfig);
93     PrintResults(result, GestureRecognizer.name , dataset);
94 };
95
96
97 let MINT = config.mint; //Maximum Training Templates
98 let MAXT = config.maxt; //Maximum Training Templates
99 let R = config.r; //Repetitions
100 let N = config.n; //Points/Shapes
101
102 for(let i=0; i < config.recognizers.length; i++){
103     let recognizer = config.recognizers[i];
104     for(let j=0; j < config.datasets.length; j++){
105         let dataset = config.datasets[j];
106         test(dataset.name, dataset.loader, recognizer.module,
            recognizer.options);
107     }
108 }

```

A.1.4 benchmarkConfig.js

```

1 // MODULES
  -----

2 const path = require('path');
3
4 // Gesture Datasets loader

```

```

5 const LeapMotionDatasetLoader = require('./implementation/
  datasets/LeapmotionDatasetLoader');
6 const SmartphoneDatasetLoader = require('./implementation/
  datasets/SmartphoneDatasetLoader');
7 const UnifiedDatasetLoader = require('./framework/datasets/
  UnifiedDatasetLoader');
8 const HandGestureDatasetLoader = require('./implementation/
  datasets/HandGestureCsvDatasetLoader');
9 const UWaveDatasetLoader = require('./implementation/datasets
  /uWaveDatasetLoader');
10
11
12 // Gesture Recognizers
13 //3D
14 const HybridP3DollarPlusXRecognizer = require('./
  implementation/recognizers/hybridp3dollarplusx-recognizer/
  recognizer').Recognizer;
15 const JackknifeRecognizer = require('./implementation/
  recognizers/jackknife-recognizer/recognizer').Recognizer;
16 const P3DollarPlusXRecognizer = require('./implementation/
  recognizers/p3dollarplusx-recognizer/recognizer').
  Recognizer;
17 const UVPRRecognizer = require('./implementation/recognizers/
  uvplus-flexible-cloud/recognizer').Recognizer;
18 const ThreeCentRecognizer = require('./implementation/
  recognizers/threecent-recognizer/recognizer').Recognizer;
19 const P3DollarPlusRecognizer = require('./implementation/
  recognizers/p3dollarplus-recognizer/recognizer').
  Recognizer;
20 const Q3DollarRecognizer = require('./implementation/
  recognizers/q3dollar-recognizer/recognizer').Recognizer;
21 //2D
22 const PDollarPlusRecognizer = require('./implementation/
  recognizers/pdollarplus/recognizer').PDollarPlusRecognizer
  ;
23
24 const fingers = ["rightThumbPosition", "rightIndexPosition",
  "rightMiddlePosition", "rightRingPosition", "
  rightPinkyPosition", "leftThumbPosition", "

```

```

    leftIndexPosition", "leftMiddlePosition", "
    leftRingPosition", "leftPinkyPosition", "righthPalmPosition
    ", "leftPalmPosition"];

25
26 // CONFIG INIT
    -----

27 var config = {};
28
29 // CONFIGURATION
    -----

30
31 config.recognizers = [
32     {
33         module: UVPR recognizer,
34         options: {
35             samplingPoints : 8,
36             articulations: ["main"]//fingers
37         }
38     },
39     {
40         module: JackknifeRecognizer,
41         options: {samplingPoints : 8}
42     },
43     {
44         module: ThreeCentRecognizer,
45         options: {
46             samplingPoints : 8,
47             pathName: "main"
48         }
49     },
50     {
51         module: P3DollarPlusRecognizer,
52         options: {
53             samplingPoints : 8,
54             pathName: "main"
55         }
56     },

```

```

57     {
58         module: P3DollarPlusXRecognizer,
59         options: {
60             samplingPoints : 8,
61             pathName: "main"
62         }
63     },
64     // {
65     //     module: HybridP3DollarPlusXRecognizer,
66     //     options: {samplingPoints : 8}
67     // },
68     {
69         module: Q3DollarRecognizer,
70         options: {
71             samplingPoints : 8,
72             pathName: "main"
73         }
74     },
75     // {
76     //     module: PDollarPlusRecognizer,
77     //     options: {
78     //         samplingPoints : 8,
79     //         pathName: "main"
80     //     }
81     // }
82 ];
83
84 config.datasets = [
85     // {
86     //     name: "guinevere_unified",
87     //     loader: UnifiedDatasetLoader
88     // }
89     // {
90     //     name: "leapmotion",
91     //     loader: LeapMotionDatasetLoader
92     // }
93     {
94         name: "HandGestureDataset_SHREC2017_csv",
95         loader: HandGestureDatasetLoader

```

```

96     }
97     // {
98     //     name: "uWaveGestureLibrary",
99     //     loader: UWaveDatasetLoader
100    // }
101    // {
102    //     name: "smartphone",
103    //     loader: SmartphoneDatasetLoader
104    // }
105 ];
106
107
108 let dirPath = path.join(__dirname, "datasets");
109 config.datasetFolder = dirPath;
110
111 config.mint = 2; //Minimum Training Templates
112 config.maxt = 8; //Maximum Training Templates
113 config.r = 100; //Repetitions
114 config.n = 8; //Points/Shapes
115
116 module.exports = config;

```

A.1.5 abstract-sensor.js

```

1 class AbstractSensor {
2
3     constructor(name) {
4         this.name = name;
5     }
6
7     /**
8      * Process one frame from the sensor.
9      * @callback frameCallback
10     * @param {Object} frame - The frame to process.
11     */
12
13     /**
14     * Process frames from the sensor. Executes the callback
15     for each frame.

```

```

15     * @param {frameCallback} callback - The callback that
      handles the frame from the sensor.
16     * @param {Object} options - A set of options for the
      sensor.
17     */
18     loop(callback, options) {
19         throw new Error('You have to implement this function'
20             );
21     }
22
23     /**
24     * Stop processing frames from the sensor.
25     */
26     stop() {
27         throw new Error('You have to implement this function'
28             );
29     }
30
31 module.exports = {
32     AbstractSensor
33 }

```

A.1.6 abstract-recognizer.js

```

1 class AbstractRecognizer {
2
3     constructor(options, dataset) {
4         // Empty
5     }
6
7     /**
8     * Add a gesture to the training set of this recognizer.
9     * @param {Object} name - The name of the gesture to add.
10    * @param {Object} sample - The gesture to add.
11    */
12    addGesture(name, sample) {

```

```

13         throw new Error('You have to implement this function'
14             );
15     }
16
17     /**
18      * Remove a gesture from the training set of this
19      * recognizer.
20      * @param {Object} name - The name of the gesture to
21      * remove.
22      */
23     removeGesture(name) {
24         throw new Error('You have to implement this function'
25             );
26     }
27
28     /**
29      * Check whether the sample corresponds to a known
30      * gesture.
31      * @param {Object} sample - A gesture sample from the
32      * sensor.
33      */
34     recognize(sample) {
35         throw new Error('You have to implement this function'
36             );
37     }
38 }
39
40 module.exports = {
41     AbstractRecognizer
42 };

```

A.1.7 abstract-segmenter.js

```

1 class AbstractSegmenter {
2     constructor(options) {
3         // Empty
4     }
5 }

```



```

6     segment(frame) {
7         throw new Error('You must implement this function');
8     }
9
10    notifyRecognition() {
11        throw new Error('You must implement this function');
12    }
13 }
14
15 module.exports = {
16     AbstractSegmenter
17 };

```

A.1.8 abstract-classifier.js

```

1 class AbstractClassifier {
2     constructor(config) {
3         // Empty
4     }
5
6     classify(frame) {
7         throw new Error('You must implement this function');
8     }
9 }
10
11 module.exports = {
12     AbstractClassifier
13 }

```

A.1.9 frame-processor.js

```

1 class FrameProcessor {
2     constructor(config) {
3         // Initialize classifier, analyzer, segmenter,
4         // dataset and recognizer
5         this.classifier = new config.classifier.module(config
6             .classifier.options);
7         this.staticAnalyzer = new config.staticAnalyzer.
8             module(config.staticAnalyzer.options);
9     }
10 }

```

```

6      this.segmenter = new config.segmenter.module(config.
          segmenter.options);
7      this.dataset = config.dataset.module.loadDataset(
          config.dataset.options.name, config.dataset.
          options.directory);
8      if (config.general.loadGesturesFromClient) {
9          this.recognizer = new config.recognizer.module(
              config.recognizer.options);
10     } else {
11         this.recognizer = new config.recognizer.module(
            config.recognizer.options, this.dataset);
12     }
13     // Keep track of enabled poses and gestures
14     this.enabledPoses = [];
15     this.enabledGestures = [];
16     // Save config
17     this.config = config;
18 }
19
20 resetContext() {
21     if (this.config.general.loadGesturesFromClient) {
22         for (const gestureName of this.enabledGesture) {
23             // TODO this.recognizer.removeGesture(
                gestureName);
24         }
25     }
26     this.enabledPoses = [];
27     this.enabledGestures = [];
28 }
29
30 enablePose(name) {
31     if (!this.enabledPoses.includes(name)) {
32         // The pose is not already enabled
33         this.enabledPoses.push(name);
34     }
35 }
36
37 enableGesture(name) {
38     if (!this.enabledGestures.includes(name)) {

```

```

39         // The gesture is not already enabled
40         if (this.config.general.loadGesturesFromClient) {
41             let gestureClass = this.dataset.
42                 getGestureClasses(name);
43             if (gestureClass) {
44                 for (template of gestureClass.getSample()
45                     ) {
46                     this.recognizer.addGesture(name,
47                         template);
48                 }
49             }
50             this.enabledGestures.push(name);
51         }
52
53     disablePose(name) {
54         var index = this.enabledPoses.indexOf(name);
55         if (index > -1) {
56             // The pose was enabled, disable it
57             this.enabledPoses.splice(index, 1);
58         }
59     }
60
61     disableGesture(name) {
62         var index = this.enabledGestures.indexOf(name);
63         if (index > -1) {
64             // The gesture was enabled, disable it
65             this.enabledGestures.splice(index, 1);
66             if (this.config.general.loadGesturesFromClient) {
67                 // TODO this.recognizer.removeGesture(name);
68             }
69         }
70     }
71
72     processFrame(frame) {
73         let staticPose = this.classifier.classify(frame);
74         if (staticPose && (!this.config.general.
75             reportGesturesFromClient || this.enabledPoses.

```

```

        includes(staticPose))) {
74     // Static pose detected
75     let data = this.staticAnalyzer.analyze(frame);
76     // this.segmenter.notifyStatic()
77     return { 'type': 'static', 'name': staticPose, '
        data': data };
78 } else {
79     // Dynamic gesture detected
80     let segment = this.segmenter.segment(frame);
81     if (segment) {
82         let { name, time, score } = this.recognizer.
            recognize(segment);
83         if (name && (!this.config.general.
            reportGesturesFromClient || this.
            enabledGestures.includes(name))) {
84             this.segmenter.notifyRecognition();
85             return { 'type': 'dynamic', 'name': name,
                'data': {} };
86         }
87     }
88 }
89 // Nothing detected
90 return null;
91 }
92 }
93
94 module.exports = {
95     FrameProcessor
96 }

```

A.1.10 UnifiedDatasetLoader.js

```

1 const path = require('path');
2 const fs = require('fs-extra');
3
4 const GestureSet = require('../gestures/gesture-set').
    GestureSet;
5 const GestureClass = require('../gestures/gesture-class').
    GestureClass;

```

```

6 const StrokeData = require('../gestures/stroke-data').
  StrokeData;
7 const Stroke = require('../gestures/stroke-data').Stroke;
8 const Point = require('../gestures/point').Point3D;
9 const Path = require('../gestures/stroke-data').Path;
10
11
12 function loadDataset(name, directory) {
13     let gestureSet = new GestureSet(name);
14     let dirPath = path.join(directory, name);
15     let gestureIndex = 0;
16
17     fs.readdirSync(dirPath).forEach((gesture) => {
18         let gestureDirPath = path.join(dirPath, gesture);
19         let gestureClass = new GestureClass(gesture,
20             gestureIndex);
21         gestureSet.addGestureClass(gestureClass);
22         fs.readdirSync(gestureDirPath).forEach((user) => {
23             let userDirPath = path.join(gestureDirPath, user)
24             ;
25             fs.readdirSync(userDirPath).forEach((file) => {
26                 let rawGesturePath = path.join(userDirPath,
27                     file);
28                 let strokeData = JSON.parse(fs.readFileSync(
29                     rawGesturePath));
30
31                 let filenameParsed = file.split(".")[0].split
32                     ("-");
33                 let gestureName = filenameParsed[0];
34                 let infosupp;
35                 if(filenameParsed.length > 2){
36                     infosupp = filenameParsed[1];
37                 }
38                 let id = parseInt(filenameParsed[
39                     filenameParsed.length-1]);
40
41                 let gestureData = new StrokeData(parseInt(
42                     user), id, infosupp);
43

```

```

37         strokeData.paths.forEach(path =>{
38             gestureData.addPath(path.label, path);
39         });
40         gestureClass.addSample(gestureData);
41     });
42 });
43     gestureIndex+=1;
44 });
45
46     return gestureSet;
47 }
48
49 function writeDataset(dataset, directory) {
50     if (fs.existsSync(directory)) {
51         fs.removeSync(directory);
52     }
53     fs.mkdirSync(directory);
54
55     dataset.getGestureClasses().forEach(gestureClass =>{
56         fs.mkdirSync(path.join(directory, gestureClass.name))
57         ;
58         gestureClass.samples.forEach(sample =>{
59             let userDirPath = path.join(directory,
60                 gestureClass.name, sample.user.toString().
61                 padStart(2, "0"));
62             if(!fs.existsSync(userDirPath)){
63                 fs.mkdirSync(userDirPath);
64             }
65             let newFilename = gestureClass.name + "-";
66             if(sample.infosupp)
67                 newFilename = newFilename + sample.infosupp +
68                 "-";
69             newFilename = newFilename + sample.id.toString().
70                 padStart(2, "0") + ".json";
71             newFilename = path.join(userDirPath, newFilename)
72             ;
73             let toWrite = {};
74             toWrite.name = gestureClass.name;
75             toWrite.subject = sample.user;

```

```

70
71     toWrite.paths = [];
72     for(let path in sample.paths){
73         toWrite.paths.push({
74             "label": sample.paths[path].label,
75             "strokes": sample.paths[path].strokes
76         });
77     }
78
79     fs.writeFileSync(newFilename, JSON.stringify(
80         toWrite, null, 2), function (err) {
81         if (err) throw err;
82         //console.log('Saved!');
83     });
84 });
85 }
86
87 module.exports = {
88     loadDataset,
89     writeDataset
90 };

```

A.1.11 gesture-set.js

```

1 class GestureSet {
2
3     constructor(name) {
4         this.name = name;
5         this.gestures = new Map();
6         this.G = 0;
7     }
8
9     addGestureClass(gestureClass){
10         this.gestures.set(gestureClass.name, gestureClass);
11         this.G += 1;
12     }
13
14     getGestureClasses(){

```

```

15     return this.gestures;
16 }
17
18 getMinTemplate(){
19     let TperG = Infinity;
20
21     for (var gestureClass of this.gestures.values()) {
22         TperG = Math.min(TperG, gestureClass.TperG);
23     }
24     return TperG;
25 }
26
27 }
28
29 module.exports = {
30     GestureSet
31 };

```

A.1.12 gesture-class.js

```

1 class GestureClass {
2
3     constructor(name, index) {
4         this.name = name;
5         this.samples = [];
6         this.index = index;
7         this.TperG = 0;
8     }
9
10    addSample(data){
11        this.samples.push(data);
12        this.TperG += 1;
13    }
14
15    getSample(){
16        return this.samples;
17    }
18
19 }

```



```
20
21 module.exports = {
22     GestureClass
23 };
```

A.1.13 stroke-data.js

```
1 class StrokeData {
2
3     constructor(user, id, infosupp) {
4         this.user = user;
5         this.id = id;
6         this.paths = {};
7         this.infosupp = infosupp;
8     }
9
10    addPath(label, path){
11        this.paths[label] = path;
12    }
13
14 }
15
16 class Stroke {
17     constructor(id) {
18         this.id = id;
19         this.points = [];
20     }
21
22     addPoint(stroke){
23         this.points.push(stroke);
24     }
25
26 }
27
28 class Path {
29     constructor(label) {
30         this.label = label;
31         this.strokes = [];
32     }
```

```

33
34     addStroke(stroke){
35         this.strokes.push(stroke);
36     }
37
38 }
39
40 module.exports = {
41     StrokeData,
42     Stroke,
43     Path
44 };

```

A.1.14 Point.js

```

1 class Point2D {
2     constructor(x, y, t) {
3         this.x = x;
4         this.y = y;
5         this.t = t;
6     }
7 }
8
9 class Point3D {
10     constructor(x, y, z, t) {
11         this.x = x;
12         this.y = y;
13         this.z = z;
14         this.t = t;
15     }
16 }
17
18 module.exports = {
19     Point2D,
20     Point3D
21 };

```

A.1.15 app-interface.js

```

1 import { w3cwebsocket as W3CWebSocket } from "websocket";
2
3 class GestureHandler {
4
5     constructor() {
6         // Save callbacks for gestures, poses, and frames
7         this.gestureHandlers = {};
8         this.poseHandlers = {};
9         this.forEachHandler = (gesture) => {};
10        this.frameHandler = (frame) => {};
11        // True if the interface is connected to the server
12        this.isConnected = false;
13        // Connect to the gesture recognizer.
14        this.client = new W3CWebSocket('ws://127.0.0.1:6442')
15        ;
16        this.client.onopen = function() {
17            console.log('WebSocket Client Connected');
18            this.isConnected = true;
19            // Register gestures to the server
20            for (const gesture of Object.keys(this.
21                gestureHandlers)) {
22                this.client.send(JSON.stringify({ 'addGesture
23                    ': gesture }));
24            }
25            // Register poses to the server
26            for (const pose of Object.keys(this.poseHandlers)
27                ) {
28                this.client.send(JSON.stringify({ 'addPose':
29                    pose }));
30            }
31        }.bind(this);
32        this.client.onmessage = function(event) {
33            let data = JSON.parse(event.data);
34            if (data.hasOwnProperty('gesture')) {
35                let gestureName = data.gesture.name;
36                if (data.gesture.type === 'dynamic') {
37                    // Dynamic gesture

```

```

33         if (this.gestureHandlers.hasOwnProperty(
34             gestureName)) {
35             this.gestureHandlers[gestureName]();
36             this.forEachHandler(gestureName);
37         }
38     } else {
39         // Pose
40         if (this.poseHandlers.hasOwnProperty(
41             gestureName)) {
42             this.poseHandlers[gestureName](data.
43                 gesture.data);
44         }
45     }
46     if (data.hasOwnProperty('frame')) {
47         this.frameHandler(data.frame);
48     }
49     }.bind(this);
50 }
51
52 /**
53  * Perform an action related to a gesture.
54  * @callback frameCallback
55  * @param {Object} frame - The data from the sensor.
56  */
57
58 /**
59  * Execute the callback each time a frame is received
60  * from the sensor.
61  * @param {frameCallback} callback - The callback that
62  * handles the frame
63  */
64 onFrame(callback) {
65     this.frameHandler = callback;
66 }
67
68 /**
69  * Perform an action for each gesture.
70  * @callback gesturesCallback

```

```

67     * @param {string} gesture - The name of the detected
        gesture.
68     */
69
70     /**
71     * Execute the callback each time any gesture is detected
        .
72     * @param {gesturesCallback} callback - The callback that
        handles the gestures.
73     */
74     onEachGesture(callback) {
75         this.forEachHandler = callback;
76     }
77
78     /**
79     * Perform an action related to a gesture.
80     * @callback gestureCallback
81     */
82
83     /**
84     * Execute the callback each time the gesture is detected
        .
85     * @param {string} gesture - The name of the gesture
        which should trigger the callback.
86     * @param {gestureCallback} callback - The callback that
        handles the gesture.
87     */
88     onGesture(gesture, callback) {
89         if (this.isConnected) {
90             this.client.send(JSON.stringify({ 'addGesture':
                gesture }));
91         }
92         this.gestureHandlers[gesture] = callback;
93     }
94
95     /**
96     * Execute the callback each time the pose is detected.
97     * @param {string} pose - The name of the pose which
        should trigger the callback.

```

```

98     * @param {poseCallback} callback - The callback that
    handles the pose.
99     */
100    onPose(pose, callback) {
101        if (this.isConnected) {
102            this.client.send(JSON.stringify({ 'addPose': pose
103                })));
104        }
105        this.poseHandlers[pose] = callback;
106    }
107
108    /**
109     * Remove the callback associated to the gesture.
110     * @param {string} gesture - The name of the gesture for
111     which the callback should be removed.
112     */
113    removeGestureHandler(gesture) {
114        if (this.gestureHandlers.hasOwnProperty(gesture)) {
115            delete this.gestureHandlers[gesture];
116            if (this.isConnected) {
117                this.client.send(JSON.stringify({ '
118                    removeGesture': gesture })));
119            }
120        }
121    }
122
123    /**
124     * Remove the callback associated to the pose.
125     * @param {string} pose - The name of the pose for which
126     the callback should be removed.
127     */
128    removePoseHandler(pose) {
129        if (this.poseHandlers.hasOwnProperty(pose)) {
130            delete this.poseHandlers[pose];
131            if (this.isConnected) {
132                this.client.send(JSON.stringify({ 'removePose
133                    ': pose })));
134            }
135        }
136    }

```

```

131     }
132
133     /**
134      * Disconnect from the gesture recognizer.
135      */
136     disconnect() {
137         this.client.close();
138     }
139 }
140
141 export default GestureHandler

```

A.2 Recognizers

A.2.1 dollar3D.js

```

1  const {
2    performance,
3    PerformanceObserver
4  } = require('perf_hooks');
5  /**
6   * $-family for hand gesture recognition
7   *   w/ 3D points;
8   *   w/ flexible cloud matching:
9   *     1) each shape from the 1st cloud with any closest
10      *     shape from the 2nd
11      *     cloud that belongs to the same articulation;
12      *     2) each unmatched shape from the 2nd cloud with any
13      *     closest shape from
14      *     the 1st cloud that belong to the same articulation.
15      *
16      * Jackknife's LeapMotion dataset, p=20, gc=8, maxT=1, n=8:
17      * 99.52% (0.28ms)
18      * Jackknife's LeapMotion dataset, p=20, gc=8, maxT=1, maxP
19      * =1, n=8: 85.69% (0.30ms)
20      * Jackknife's LeapMotion dataset, p=20, gc=8, maxT=1, maxP
21      * =2, n=8: 91.87% (0.47ms)
22      * Jackknife's LeapMotion dataset, p=20, gc=8, maxT=1, maxP
23      * =3, n=8: 93.62% (0.63ms)

```

```

18  * Jackknife's LeapMotion dataset, p=20, gc=8, maxT=1, maxP
    =4, n=8: 94.63% (0.79ms)
19  * Jackknife's LeapMotion dataset, p=20, gc=8, maxT=1, maxP
    =5, n=8: 95.33% (0.93ms)
20  */
21
22
23 /**
24  * Point constructor.
25  */
26 function Point(x, y, z) {
27     // (x, y, z) coordinates
28     this.x = x;
29     this.y = y;
30     this.z = z;
31 }
32
33 /**
34  * Gesture constructor.
35  */
36 function Gesture(articulations, name = 'unknown') {
37     // name of the gesture class
38     this.name = name;
39     // array of articulations' points
40     this.articulations = articulations;
41 }
42
43 /**
44  * UVPRecognizer constructor.
45  */
46 function UVPRecognizer(numberOfArticulations, numberOfPoints)
    {
47     // number of articulations (paths) per gesture
48     this.numberOfArticulations = numberOfArticulations;
49     // number of points per articulation required to represent
        a gesture
50     this.numberOfPoints = numberOfPoints;
51     // array of stored training templates
52     this.trainingTemplates = [];

```



```

53 }
54
55 /**
56  * Transform an array of articulations' points into a
57  * template via
58  * preprocessing.
59  * @return true the template was successfully saved; false
60  * otherwise
61  */
62 UVPRecognizer.prototype.storeTemplate = function(
63     articulations, name) {
64     if (articulations.length == this.numberOfArticulations) {
65         let template = new Gesture(this.preprocess(articulations)
66             , name);
67         this.trainingTemplates.push(template);
68         return true;
69     }
70     return false; // error: not enough articulations
71 }
72
73 /**
74  * Determine the gesture class of an array of articulations'
75  * points (candidate)
76  * after preprocessing and cloud-matching against the stored
77  * training templates.
78  *
79  * @return an array with the least dissimilar training
80  * template and the time
81  * required to perform the recognition in ms.
82  */
83 UVPRecognizer.prototype.recognize = function(articulations) {
84     if (articulations.length == this.numberOfArticulations) {
85         // start timer
86         let t0 = performance.now();
87
88         let minDissimilarity = +Infinity;
89         let bestTemplate = -1;
90     }
91 }

```

```

85     // preprocess the points to represent the candidate
      gesture
86     let candidate = new Gesture(this.preprocess(articulations
      ));
87
88     // cloud-matching against all stored training templates
89     for (let t = 0; t < this.trainingTemplates.length; t +=
      1) {
90         let dissimilarity = this.cloudMatching(
91             candidate.articulations, this.trainingTemplates[t].
              articulations, minDissimilarity
92         );
93
94         // if less dissimilar: update info
95         if (dissimilarity < minDissimilarity) {
96             minDissimilarity = dissimilarity;
97             bestTemplate = t;
98         }
99     }
100
101     // stop timer
102     let t1 = performance.now();
103     let res = (this.trainingTemplates.length === 0 ||
      bestTemplate === -1) ? "" : this.trainingTemplates[
      bestTemplate].name;
104     return [res, t1 - t0];
105 }
106 return [false, 0]; // error: not enough articulations
107 }
108
109 /**
110  * Transform an array of articulations' points into an array
      of articulations'
111  * points after resampling, scaling, and translation.
112  *
113  * @return an array of articulations' points.
114  */
115 UVPRecognizer.prototype.preprocess = function(articulations)
      {

```

```

116     return this.translate(
117         this.scale(
118             this.resample(articulations)
119         ),
120         new Point(0, 0, 0)
121     );
122 }
123
124 /**
125  * Resample an array of articulations' points.
126  *
127  * @return an array of resampled articulations' points.
128  */
129 UVPRecognizer.prototype.resample = function(articulations) {
130     let resampledArticulations = [];
131     let arts = [];
132     for (let a = 0; a < this.numberOfArticulations; a += 1) {
133         resampledArticulations[a] = [articulations[a][0]];
134         // avoid modifying the original array (cfr call to splice
135             method below)
136         arts[a] = articulations[a].slice(0, articulations[a].
137             length);
138     }
139
140     // the interval between two resampled points depends of the
141         number of shapes
142     // and the total length of each articulation's points
143     let intervals = [];
144     for (let a = 0; a < this.numberOfArticulations; a += 1) {
145         intervals[a] = this.pathLength(articulations[a]) / (this.
146             numberOfPoints - 1);
147     }
148
149     // resample the articulation's point when it is too far
150         away from the previous
151     let dist = [];
152     for (let a = 0; a < this.numberOfArticulations; a += 1) {
153         dist[a] = 0.0;
154     }

```

```

150   for (let a = 0; a < this.numberOfArticulations; a += 1) {
151       for (let i = 1; i < arts[a].length; i += 1) {
152           if(intervals[a] === 0)
153               {
154                   resampledArticulations[a] = Array(this.
                       numberOfArticulations).fill(new Point(0,0,0));
155                   break;
156               }
157           let dist2 = this.betweenPointsEuclideanDistance(arts[a]
                       ][i - 1], arts[a][i]);
158           if ((dist[a] + dist2) >= intervals[a]) {
159               let p = new Point(
160                   arts[a][i - 1].x + ((intervals[a] - dist[a]) /
                       dist2) * (arts[a][i].x - arts[a][i - 1].x),
161                   arts[a][i - 1].y + ((intervals[a] - dist[a]) /
                       dist2) * (arts[a][i].y - arts[a][i - 1].y),
162                   arts[a][i - 1].z + ((intervals[a] - dist[a]) /
                       dist2) * (arts[a][i].z - arts[a][i - 1].z)
163               );
164               resampledArticulations[a].push(p);
165               arts[a].splice(i, 0, p);
166               dist[a] = 0.0;
167           }
168           else dist[a] += dist2;
169       }
170   }
171
172   // it may fall a rounding-error short of adding the last
   articulation's point
173   for (let a = 0; a < this.numberOfArticulations; a += 1) {
174       while (resampledArticulations[a].length <= this.
           numberOfPoints) {
175           resampledArticulations[a].push(arts[a][arts[a].length -
               1]);
176       }
177   }
178
179   return resampledArticulations;
180 }

```

```

181
182 /**
183  * Scale all articulations' points.
184  *
185  * @return the scaled articulations' points.
186  */
187 UVPRecognizer.prototype.scale = function(articulations) {
188     // compute the min and max values for x, y, and z
189     coordinates
190     let minX = +Infinity, maxX = -Infinity;
191     let minY = +Infinity, maxY = -Infinity;
192     let minZ = +Infinity, maxZ = -Infinity;
193     for (let a = 0; a < this.numberOfArticulations; a += 1) {
194         for (let i = 0; i < this.numberOfPoints; i += 1) {
195             minX = Math.min(minX, articulations[a][i].x);
196             minY = Math.min(minY, articulations[a][i].y);
197             minZ = Math.min(minZ, articulations[a][i].z);
198             maxX = Math.max(maxX, articulations[a][i].x);
199             maxY = Math.max(maxY, articulations[a][i].y);
200             maxZ = Math.max(maxZ, articulations[a][i].z);
201         }
202     }
203     // scale all articulations' points
204     let size = Math.max(maxX - minX, Math.max(maxY - minY, maxZ
205         - minZ));
206     let newArticulations = [];
207     for (let a = 0; a < this.numberOfArticulations; a += 1) {
208         newArticulations[a] = [];
209         for (let i = 0; i < this.numberOfPoints; i += 1) {
210             newArticulations[a][i] = new Point(
211                 (articulations[a][i].x - minX) / size,
212                 (articulations[a][i].y - minY) / size,
213                 (articulations[a][i].z - minZ) / size
214             );
215         }
216     }
217     return newArticulations;
218 }

```

```

218 /**
219  * Translate all articulations' points towards the reference
220  *
221  * @return the translated articulations' points.
222  */
223 UVPRecognizer.prototype.translate = function(articulations,
224     reference) {
225     let newArticulations = [];
226     let centroid = this.centroid(articulations);
227     for (let a = 0; a < this.numberOfArticulations; a += 1) {
228         newArticulations[a] = [];
229         for (let i = 0; i < this.numberOfPoints; i += 1) {
230             newArticulations[a][i] = new Point(
231                 articulations[a][i].x + reference.x - centroid.x,
232                 articulations[a][i].y + reference.y - centroid.y,
233                 articulations[a][i].z + reference.z - centroid.z
234             );
235         }
236     }
237     return newArticulations;
238 }
239 /**
240  * Compute the global centroid of all articulations' points.
241  *
242  * @return the centroid of all articulations' points.
243  */
244 UVPRecognizer.prototype.centroid = function(articulations) {
245     let count = 0;
246     let dX = 0.0, dY = 0.0, dZ = 0.0;
247     for (let a = 0; a < this.numberOfArticulations; a += 1) {
248         for (let i = 0; i < articulations[a].length; i += 1) {
249             dX += articulations[a][i].x;
250             dY += articulations[a][i].y;
251             dZ += articulations[a][i].z;
252             count += 1;
253         }
254     }

```

```

255     return new Point(dX / count, dY / count, dZ / count);
256 }
257
258 /**
259  * Compute the path length of an array of points: the sum of
260  * the Euclidean
261  * distance between the consecutive points.
262  * @return the path length of an array of points.
263  */
264 UVPRecognizer.prototype.pathLength = function(points) {
265     let length = 0.0;
266     for (let i = 1; i < points.length - 1; i += 1) {
267         length += this.betweenPointsEuclideanDistance(points[i -
268             1], points[i]);
269     }
270     return length;
271 }
272
273 /**
274  * Compute the Euclidean distance between two points a and b
275  * .
276  * @return the Euclidean distance between two points a and b
277  * .
278  */
279 UVPRecognizer.prototype.betweenPointsEuclideanDistance =
280     function(a, b) {
281         let dX = b.x - a.x;
282         let dY = b.y - a.y;
283         let dZ = b.z - a.z;
284         return Math.sqrt(dX * dX + dY * dY + dZ * dZ);
285     }
286
287 /**
288  * Compute the dissimilarity score between two arrays of
289  * articulations via the
290  * flexible cloud matching procedure in both directions.
291  *

```

```

288  * @return the dissimilarity score between two arrays of
      articulations.
289  */
290  UVPRecognizer.prototype.cloudMatching = function(
      articulationsA, articulationsB, minSoFar) {
291      return Math.min(
292          this.cloudDistance(articulationsA, articulationsB,
              minSoFar),
293          this.cloudDistance(articulationsB, articulationsA,
              minSoFar)
294      );
295  }
296
297  /**
298   * Compute the dissimilarity score between two arrays of
      articulations via
299   * the flexible cloud matching procedure: shapes from the
      first array can be
300   * matched to any shape that belongs to the same
      articulation in the second
301   * array, and shapes from the second array that have not
      been matched yet can
302   * be matched to any shape that belongs to the same
      articulation in the first
303   * array.
304   *
305   * @return the dissimilarity score between two arrays of
      articulations.
306   */
307  UVPRecognizer.prototype.cloudDistance = function(
      articulationsA, articulationsB, minSoFar) {
308      let dissimilarity = 0;
309
310      // all shapes from articulationsB are *not* matched for now
311      let matchedPoints = [];
312      for (let b = 0; b < this.numberOfArticulations; b += 1) {
313          matchedPoints[b] = [];
314          for (let j = 0; j < this.numberOfPoints; j += 1) {
315              matchedPoints[b][j] = false;

```



```

316     }
317 }
318
319 // match each shape from articulationsA with the closest
    shape from
320 // articulationsB that belongs to the same articulation
321 for (let a = 0; a < this.numberOfArticulations; a += 1) {
322     for (let i = 0; i < this.numberOfPoints; i += 1) {
323         let minD = +Infinity;
324         let indexPoint = -1;
325         for (let j = 0; j < this.numberOfPoints; j += 1) {
326             let d = this.betweenPointsEuclideanDistance(
                articulationsA[a][i], articulationsB[a][j]);
327             if (d < minD) {
328                 minD = d;
329                 indexPoint = j;
330             }
331         }
332         dissimilarity += minD;
333         matchedPoints[a][indexPoint] = true;
334         if (dissimilarity > minSoFar) return dissimilarity; //
            early abandoning
335     }
336 }
337
338 // match each shape from articulationsB that has not been
    matched yet with the
339 // closest shape from articulationsA that belongs to the
    same articulation
340 for (let b = 0; b < this.numberOfArticulations; b += 1) {
341     for (let j = 0; j < this.numberOfPoints; j += 1) {
342         if (!matchedPoints[b][j]) {
343             let minD = +Infinity;
344             let indexPoint = -1;
345             for (let i = 0; i < this.numberOfPoints; i += 1) {
346                 let d = this.betweenPointsEuclideanDistance(
                    articulationsA[b][i], articulationsB[b][j]);
347                 if (d < minD) minD = d;
348             }

```

```

349         dissimilarity += minD;
350         matchedPoints[b][j] = true;
351         if (dissimilarity > minSoFar) return dissimilarity;
           // early abandoning
352     }
353 }
354 }
355
356 return dissimilarity;
357 }
358
359 module.exports = {
360     Point,
361     UVPRecognizer
362 };

```

A.2.2 dollar3D-interface.js

```

1  const recognizer = require('.../.../framework/recognizers/
    Recognizer');
2  const dollar = require('./dollar');
3
4  class Recognizer extends recognizer.Recognizer{
5
6      static name = "DollarRecognizer";
7
8      constructor(options, dataset) {
9          super();
10         this.N = options.samplingPoints;
11         this.articulations = options.articulations;
12         this.recognizer = new dollar.UVPRecognizer(this.
            articulations.length, this.N);
13         if (dataset !== undefined){
14             dataset.getGestureClasses().forEach((gesture, key
                , self) => {
15                 gesture.getSample().forEach(sample => {
16                     this.addGesture(gesture.name, sample)
17                     ;
18                 }
19             )
20         }

```

```

18         );
19     });
20 }
21 }
22
23 addGesture(name, sample){
24     this.recognizer.storeTemplate(this.convert(sample),
25         name);
26 }
27
28 recognize(sample){
29     let result = this.recognizer.recognize(this.convert(
30         sample));
31     return {name:result[0], time: result[1]};
32 }
33
34 convert(sample){
35     let points =[];
36     for(let path in sample.paths){
37         let strokes = sample.paths[path].strokes;
38         let articulationPoints = [];
39         strokes.forEach(stroke =>{
40             articulationPoints = articulationPoints.
41                 concat(stroke.points);
42         });
43         points.push(articulationPoints);
44     }
45     return points;
46 }
47
48
49 module.exports = {
50     Recognizer
51 };

```

A.2.3 jackknife-interface.js

```
1 const AbstractRecognizer = require('../../../../framework/
    recognizers/abstract-recognizer').AbstractRecognizer;
2 const jackknife_blades = require('./jackknife/jackknife').
    jackknife_blades;
3 const Jackknife = require('./jackknife/jackknife_recognizer')
    .Jackknife;
4 const Vector = require('./jackknife/vector').Vector;
5 const Sample = require('./jackknife/sample').Sample;
6
7 class Recognizer extends AbstractRecognizer {
8
9     static name = "JackknifeRecognizer";
10
11     constructor(options, dataset) {
12         super();
13         this.N = options.samplingPoints;
14         let blades = new jackknife_blades();
15         blades.set_ip_defaults();
16         this.jackknifeRecognizer = new Jackknife(blades)
17         if (dataset !== undefined){
18             dataset.getGestureClasses().forEach((gesture) => {
19                 gesture.getSample().forEach(sample => {
20                     this.addGesture(gesture.name, sample, false);
21                 }
22             );
23         });
24         this.jackknifeRecognizer.train(6, 2, 1.0);
25     }
26
27     recognize(sample) {
28         let jackknifeSample = convert(sample);
29         if (!jackknifeSample) {
30             return { name: "", time: 0.0 };
31         }
32         let t0 = Date.now();
33         let ret = this.jackknifeRecognizer.classify(
34             jackknifeSample);
```

```

35     let t1 = Date.now();
36     return (ret == -1) ? { name: "", time: t1-t0 } : { name:
      ret, time: t1-t0 };
37 }
38
39 addGesture(name, sample, train = false) {
40     let jackknifeSample = convert(sample, name);
41     if (jackknifeSample) {
42         this.jackknifeRecognizer.add_template(
            jackknifeSample);
43         if (train) {
44             this.jackknifeRecognizer.train(6, 2, 1.0);
45         }
46     }
47 }
48 }
49
50 function convert(sample, name) {
51     let jackknifeSample;
52     if (name) {
53         jackknifeSample = new Sample(0, name);
54     } else {
55         jackknifeSample = new Sample();
56     }
57
58     let pathsLabels = Object.keys(sample.paths).sort();
59     // check min distance START
60     let maxMovement = 0;
61     let threshold = 40;
62     let initPoints = {};
63     for (const articulation of pathsLabels) {
64         initPoints[articulation] = sample.paths[articulation]
            .strokes[0].points[0];
65     }
66     // check min distance END
67
68     let nFrames = sample.paths[pathsLabels[0]].strokes[0].
        points.length;
69     let trajectory = [];

```

```

70     for (let i = 0; i < nFrames; i++) {
71         let vCoordinates = [];
72         for (const articulation of pathsLabels) {
73             let point = sample.paths[articulation].strokes
74                 [0].points[i];
75             // check min distance START
76             let articulationMovement = distance(point,
77                 initPoints[articulation]);
78             maxMovement = Math.max(maxMovement,
79                 articulationMovement);
80             // check min distance END
81             vCoordinates.push(point.x);
82             vCoordinates.push(point.y);
83             vCoordinates.push(point.z);
84         }
85         trajectory.push(new Vector(vCoordinates));
86     }
87     jackknifeSample.add_trajectory(trajectory);
88
89     return maxMovement > threshold ? jackknifeSample : null;
90     //return jackknifeSample;
91 }
92
93 function distance(p1, p2) // Euclidean distance between two
94     points
95 {
96     var dx = p2.x - p1.x;
97     var dy = p2.y - p1.y;
98     var dz = p2.z - p1.z;
99     return Math.sqrt(dx * dx + dy * dy + dz * dz);
100 }
101
102 module.exports = {
103     Recognizer
104 };

```

A.2.4 p3dollarplus-recognizer.js

```

1 const AbstractRecognizer = require('../../../../framework/
    recognizers/abstract-recognizer').AbstractRecognizer;
2
3 /**
4  * The $P+ Point-Cloud Recognizer (JavaScript version)
5  *
6  * Radu-Daniel Vatavu, Ph.D.
7  * University Stefan cel Mare of Suceava
8  * Suceava 720229, Romania
9  * vatavu@eed.usv.ro
10 *
11 * The academic publication for the $P+ recognizer, and what
    should be
12 * used to cite it, is:
13 *
14 *      Vatavu, R.-D. (2017). Improving gesture recognition
        accuracy on
15 *      touch screens for users with low vision. Proceedings
        of the ACM
16 *      Conference on Human Factors in Computing Systems (CHI
        '17). Denver,
17 *      Colorado (May 6-11, 2017). New York: ACM Press, pp.
        4667-4679.
18 *      https://dl.acm.org/citation.cfm?id=3025941
19 *
20 * This software is distributed under the "New BSD License"
        agreement:
21 *
22 * Copyright (C) 2017-2018, Radu-Daniel Vatavu and Jacob O.
        Wobbrock. All
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```

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46 * SUCH DAMAGE.
47 **/
48
49 //

```



```

50 // Point class
51 //
52 class Point {
53     constructor(x, y, z, id, angle = 0.0) {
54         this.x = x;
55         this.y = y;
56         this.z = z;
57         this.id = id;
58         this.angle = angle; // normalized turning angle, $P+
59     }
60 }
61
62 //
63 // PointCloud class: a point-cloud template
64 //
65 function PointCloud(name, points) // constructor
66 {
67     this.Name = name;
68     this.Points = Resample(points, NumPoints);
69     this.Points = Scale(this.Points);
70     this.Points = TranslateTo(this.Points, Origin);
71     this.Points = ComputeNormalizedTurningAngles(this.Points);
72     // $P+
73 }
74
75 //
76 // PDollarPlusRecognizer constants
77 //
78 let NumPoints = 8;
79 let pathName;
80 const Origin = new Point(0, 0, 0, 0);
81
82 //
83 // PDollarPlusRecognizer class
84 //
85 class Recognizer extends AbstractRecognizer {
86     static name = "P3DollarPlusRecognizer";
87 }

```

```

88     constructor(options, dataset) {
89         super();
90         NumPoints = options.samplingPoints;
91         pathName = options.pathName;
92         this.PointClouds = new Array();
93         if (dataset !== undefined){
94             dataset.getGestureClasses().forEach((gesture, key, self
95                 ) => {
96                 gesture.getSample().forEach(sample => {
97                     this.addGesture(gesture.name, sample);
98                 }
99             });
100         }
101     }
102
103     //
104     // The $P+ Point-Cloud Recognizer API begins here -- 3
105     // methods: Recognize(), AddGesture(), DeleteUserGestures()
106     //
107     recognize(sample) {
108         let points = convert(sample);
109         if(points.length === 0)
110             return { name: "", time: 0, score: 0.0 };
111         let t0 = Date.now();
112         var candidate = new PointCloud("", points);
113
114         var u = -1;
115         var b = +Infinity;
116         for (var i = 0; i < this.PointClouds.length; i++) // for
117             each point-cloud template
118         {
119             var d = Math.min(
120                 CloudDistance(candidate.Points, this.PointClouds[i].
121                     Points, b),
122                 CloudDistance(this.PointClouds[i].Points, candidate.
123                     Points, b)
124             ); // $P+
125             if (d < b) {

```

```

122         b = d; // best (least) distance
123         u = i; // point-cloud index
124     }
125 }
126 let t1 = Date.now();
127 return (u == -1) ? { name: "", time: t1-t0, score: 0.0 }
    : { name: this.PointClouds[u].Name, time: t1-t0, score
    : b > 1.0 ? 1.0 / b : 1.0 };
128 }
129
130 addGesture(name, sample) {
131     let points = convert(sample);
132     this.PointClouds[this.PointClouds.length] = new
        PointCloud(name, points);
133     var num = 0;
134     for (var i = 0; i < this.PointClouds.length; i++) {
135         if (this.PointClouds[i].Name == name)
136             num++;
137     }
138     return num;
139 }
140 }
141
142 function convert(sample) {
143     let points = [];
144     sample.paths[pathName].strokes.forEach((stroke, stroke_id)
        => {
145         stroke.points.forEach((point) => {
146             points.push(new Point(point.x, point.y, point.z,
                stroke_id));
147         });
148     });
149     return points;
150 }
151
152 //
153 // Private helper functions from here on down
154 //

```

```

155 function CloudDistance(pts1, pts2, minSoFar) // revised for
    $P+
156 {
157     var matched = new Array(pts1.length); // pts1.length ==
        pts2.length
158     for (var k = 0; k < pts1.length; k++)
159         matched[k] = false;
160     var sum = 0;
161     for (var i = 0; i < pts1.length; i++)
162     {
163         var index = -1;
164         var min = +Infinity;
165         for (var j = 0; j < pts1.length; j++)
166         {
167             var d = DistanceWithAngle(pts1[i], pts2[j]);
168             if (d < min) {
169                 min = d;
170                 index = j;
171             }
172         }
173         matched[index] = true;
174         sum += min;
175         if (sum >= minSoFar) return sum; // early abandoning
176     }
177     for (var j = 0; j < matched.length; j++)
178     {
179         if (!matched[j]) {
180             var min = +Infinity;
181             for (var i = 0; i < pts1.length; i++) {
182                 var d = DistanceWithAngle(pts1[i], pts2[j]);
183                 if (d < min)
184                     min = d;
185             }
186             sum += min;
187             if (sum >= minSoFar) return sum; // early abandoning
188         }
189     }
190     return sum;
191 }

```

```

192
193 function Resample(points, n)
194 {
195     var I = PathLength(points) / (n - 1); // interval length
196     var D = 0.0;
197     var newpoints = new Array(points[0]);
198     for (var i = 1; i < points.length; i++)
199     {
200         if (points[i].id == points[i-1].id)
201         {
202             var d = Distance(points[i-1], points[i]);
203             if ((D + d) >= I)
204             {
205                 var qx = points[i-1].x + ((I - D) / d) * (points[i].x
206                     - points[i-1].x);
207                 var qy = points[i-1].y + ((I - D) / d) * (points[i].y
208                     - points[i-1].y);
209                 var qz = points[i-1].z + ((I - D) / d) * (points[i].z
210                     - points[i-1].z);
211                 var q = new Point(qx, qy, qz, points[i].id);
212                 newpoints[newpoints.length] = q; // append new point
213                 'q'
214                 points.splice(i, 0, q); // insert 'q' at position i
215                 in points s.t. 'q' will be the next i
216                 D = 0.0;
217             }
218             else D += d;
219         }
220     }
221     if (newpoints.length == n - 1) // sometimes we fall a
222         rounding-error short of adding the last point, so add it
223         if so
224         newpoints[newpoints.length] = new Point(points[points.
225             length - 1].x, points[points.length - 1].y, points[
226                 points.length - 1].z, points[points.length - 1].id);
227     return newpoints;
228 }
229
230 function Scale(points)

```

```

222 {
223     var minX = +Infinity, maxX = -Infinity, minY = +Infinity,
        maxY = -Infinity, minZ = +Infinity, maxZ = -Infinity;
224     for (var i = 0; i < points.length; i++) {
225         minX = Math.min(minX, points[i].x);
226         minY = Math.min(minY, points[i].y);
227         minZ = Math.min(minZ, points[i].z);
228         maxX = Math.max(maxX, points[i].x);
229         maxY = Math.max(maxY, points[i].y);
230         maxZ = Math.max(maxY, points[i].z);
231     }
232     var size = Math.max(maxX - minX, maxY - minY, maxZ - minZ);
233     var newpoints = new Array();
234     for (var i = 0; i < points.length; i++) {
235         var qx = (points[i].x - minX) / size;
236         var qy = (points[i].y - minY) / size;
237         var qz = (points[i].z - minZ) / size;
238         newpoints[newpoints.length] = new Point(qx, qy, qz,
            points[i].id);
239     }
240     return newpoints;
241 }
242
243 function TranslateTo(points, pt) // translates points'
    centroid
244 {
245     var c = Centroid(points);
246     var newpoints = new Array();
247     for (var i = 0; i < points.length; i++) {
248         var qx = points[i].x + pt.x - c.x;
249         var qy = points[i].y + pt.y - c.y;
250         var qz = points[i].z + pt.z - c.z;
251         newpoints[newpoints.length] = new Point(qx, qy, qz,
            points[i].id);
252     }
253     return newpoints;
254 }
255
256 function ComputeNormalizedTurningAngles(points) // $P+

```

```

257 {
258     var newpoints = new Array();
259     newpoints[0] = new Point(points[0].x, points[0].y, points
        [0].z, points[0].id); // first point
260     for (var i = 1; i < points.length - 1; i++)
261     {
262         var dx = (points[i+1].x - points[i].x) * (points[i].x -
            points[i-1].x);
263         var dy = (points[i+1].y - points[i].y) * (points[i].y -
            points[i-1].y);
264         var dz = (points[i+1].z - points[i].z) * (points[i].z -
            points[i-1].z);
265         var dn = Distance(points[i+1], points[i]) * Distance(
            points[i], points[i-1]);
266         var cosangle = Math.max(-1.0, Math.min(1.0, (dx + dy + dz
            ) / dn)); // ensure [-1,+1]
267         var angle = Math.acos(cosangle) / Math.PI; // normalized
            angle
268         newpoints[newpoints.length] = new Point(points[i].x,
            points[i].y, points[i].z, points[i].id, angle);
269     }
270     newpoints[newpoints.length] = new Point( // last point
        points[points.length - 1].x,
271        points[points.length - 1].y,
272        points[points.length - 1].z,
273        points[points.length - 1].id);
274     return newpoints;
275 }
276
277
278 function Centroid(points)
279 {
280     var x = 0.0, y = 0.0, z = 0.0;
281     for (var i = 0; i < points.length; i++) {
282         x += points[i].x;
283         y += points[i].y;
284         z += points[i].z;
285     }
286     x /= points.length;
287     y /= points.length;

```

```

288     z /= points.length;
289     return new Point(x, y, z, 0);
290 }
291
292 function PathLength(points) // length traversed by a point
    path
293 {
294     var d = 0.0;
295     for (var i = 1; i < points.length; i++) {
296         if (points[i].id == points[i-1].id)
297             d += Distance(points[i-1], points[i]);
298     }
299     return d;
300 }
301
302 function DistanceWithAngle(p1, p2) // $P+
303 {
304     var dx = p2.x - p1.x;
305     var dy = p2.y - p1.y;
306     var dz = p2.z - p1.z;
307     var da = p2.angle - p1.angle;
308     return Math.sqrt(dx * dx + dy * dy + dz * dz + da * da);
309 }
310
311 function Distance(p1, p2) // Euclidean distance between two
    points
312 {
313     var dx = p2.x - p1.x;
314     var dy = p2.y - p1.y;
315     var dz = p2.z - p1.z;
316     return Math.sqrt(dx * dx + dy * dy + dz * dz);
317 }
318
319 module.exports = {
320     Point,
321     Recognizer
322 };

```


A.2.5 q3dollar-recognizer.js

```
1 const AbstractRecognizer = require('../.../framework/
    recognizers/abstract-recognizer').AbstractRecognizer;
2
3 /**
4  * The $Q Super-Quick Recognizer (JavaScript version)
5  *
6  * Javascript version:
7  *
8  * Nathan Magrofuoco
9  * Universite Catholique de Louvain
10 * Louvain-la-Neuve, Belgium
11 * nathan.magrofuoco@uclouvain.be
12 *
13 * Original $Q authors (C# version):
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24 * lanthony@cise.ufl.edu
25 *
26 * Jacob O. Wobbrock, Ph.D.
27 * The Information School | DUB Group
28 * University of Washington
29 * Seattle, WA, USA 98195-2840
30 * wobbrock@uw.edu
31 *
32 * The academic publication for the $Q recognizer, and what
    should be
33 * used to cite it, is:
34 *
35 *   Vatavu, R.-D., Anthony, L. and Wobbrock, J.O. (2018).
    $Q: A super-quick,
```

```

36 * articulation-invariant stroke-gesture recognizer for
    low-resource devices.
37 * Proceedings of the ACM Conference on Human-Computer
    Interaction with Mobile
38 * Devices and Services (MobileHCI '18). Barcelona, Spain
    (September 3-6, 2018).
39 * New York: ACM Press. Article No. 23.
40 * https://dl.acm.org/citation.cfm?id=3229434.3229465
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69  * SUCH DAMAGE.
70  **/
71
72  //
73  // Point class
74  //
75  class Point {
76      constructor(x, y, z, id) {
77          this.x = x;
78          this.y = y;
79          this.z = z;
80          this.id = id;
81          this.intX = 0; // for indexing into the LUT
82          this.intY = 0; // for indexing into the LUT
83          this.intZ = 0; // for indexing into the LUT
84      }
85  }
86
87  //

```

```

88 // PointCloud class
89 //
90 class PointCloud {
91     constructor(name, points) {
92         this.Name = name;
93         this.Points = Resample(points, NumPoints);
94         this.Points = Scale(this.Points);
95         this.Points = TranslateTo(this.Points, Origin);
96         this.Points = MakeIntCoords(this.Points); // fills in (
            intX, intY, intZ) values
97         this.LUT = ComputeLUT(this.Points);
98     }
99 }
100
101 //
102 // QDollarRecognizer constants
103 //
104 let NumPoints = 32;
105 let pathName;
106 const Origin = new Point(0, 0, 0, 0);
107 const MaxIntCoord = 1024; // (intX, intY, intZ) range from
    [0, MaxIntCoord - 1]
108 const LUTSize = 16; // default size of the lookup table is 16
    x 16 x 16
109 const LUTScaleFactor = MaxIntCoord / LUTSize; // used to
    scale from (intX, intY, intZ) to LUT
110 //
111 // Q3DollarRecognizer class
112 //
113 class Recognizer extends AbstractRecognizer {
114
115     static name = "Q3DollarRecognizer";
116
117     constructor(options, dataset) {
118         super();
119         NumPoints = options.samplingPoints;
120         pathName = options.pathName;
121         this.PointClouds = new Array();
122

```

```

123     if (dataset !== undefined){
124         dataset.getGestureClasses().forEach((gesture, key, self
125             ) => {
126             gesture.getSample().forEach(sample => {
127                 this.addGesture(gesture.name, sample);
128             }
129         });
130     }
131 }
132
133 addGesture(name, sample){
134     let points = convert(sample);
135     this.PointClouds.push(new PointCloud(name, points));
136     var num = 0;
137     for (var i = 0; i < this.PointClouds.length; i++) {
138         if (this.PointClouds[i].Name == name)
139             num++;
140     }
141     return num;
142 }
143
144 recognize(sample){
145     let points = convert(sample);
146     var t0 = Date.now();
147     var candidate = new PointCloud("", points);
148
149     var u = -1;
150     var b = +Infinity;
151     for (var i = 0; i < this.PointClouds.length; i++) // for
152         each point-cloud template
153     {
154         var d = CloudMatch(candidate, this.PointClouds[i], b);
155         if (d < b) {
156             b = d; // best (least) distance
157             u = i; // point-cloud index
158         }
159     }
160     var t1 = Date.now();

```

```

160     return (u == -1) ? { name: "", time: t1-t0 } : { name:
        this.PointClouds[u].Name, time: t1-t0 };
161 }
162 }
163
164 function convert(sample) {
165     let points = [];
166     sample.paths[pathName].strokes.forEach((stroke, stroke_id)
        => {
167         stroke.points.forEach((point) => {
168             points.push(new Point(point.x, point.y, point.z,
                stroke_id));
169         });
170     });
171     return points;
172 }
173
174 //
175 // Private helper functions from here on down
176 //
177 function CloudMatch(candidate, template, minSoFar)
178 {
179     var n = candidate.Points.length;
180     var step = Math.floor(Math.pow(n, 0.5));
181
182     var LB1 = ComputeLowerBound(candidate.Points, template.
        Points, step, template.LUT);
183     let LB2 = ComputeLowerBound(template.Points, candidate.
        Points, step, candidate.LUT);
184
185     for (var i = 0, j = 0; i < n; i += step, j++) {
186         if (LB1[j] < minSoFar)
187             minSoFar = Math.min(minSoFar, CloudDistance(candidate.
                Points, template.Points, i, minSoFar));
188         if (LB2[j] < minSoFar)
189             minSoFar = Math.min(minSoFar, CloudDistance(template.
                Points, candidate.Points, i, minSoFar));
190     }
191     return minSoFar;

```

```

192 }
193 function CloudDistance(pts1, pts2, start, minSoFar)
194 {
195     var n = pts1.length;
196     var unmatched = new Array(); // indices for pts2 that are
        not matched
197     for (var j = 0; j < n; j++)
198         unmatched[j] = j;
199     var i = start; // start matching with point 'start' from
        pts1
200     var weight = n; // weights decrease from n to 1
201     var sum = 0.0; // sum distance between the two clouds
202     do
203     {
204         var u = -1;
205         var b = +Infinity;
206         for (var j = 0; j < unmatched.length; j++)
207         {
208             d = SqrEuclideanDistance(pts1[i], pts2[unmatched[j]]);
209             if (d < b) {
210                 b = d;
211                 u = j;
212             }
213         }
214         unmatched.splice(u, 1); // remove item at index 'u'
215         sum += weight * b;
216         if (sum >= minSoFar)
217             return sum; // early abandoning
218         weight--;
219         i = (i + 1) % n;
220     } while (i != start);
221     return sum;
222 }
223 function ComputeLowerBound(pts1, pts2, step, LUT)
224 {
225     var n = pts1.length;
226     var LB = new Array(Math.floor(n / step) + 1);
227     var SAT = new Array(n);
228     LB[0] = 0.0;

```

```

229   for (var i = 0; i < n; i++)
230   {
231       var x = Math.round(pts1[i].intX / LUTScaleFactor);
232       var y = Math.round(pts1[i].intY / LUTScaleFactor);
233       var z = Math.round(pts1[i].intZ / LUTScaleFactor);
234       var index = LUT[x][y][z];
235       var d = SqrEuclideanDistance(pts1[i], pts2[index]);
236       SAT[i] = (i == 0) ? d : SAT[i - 1] + d;
237       LB[0] += (n - i) * d;
238   }
239   for (var i = step, j = 1; i < n; i += step, j++)
240       LB[j] = LB[0] + i * SAT[n-1] - n * SAT[i-1];
241   return LB;
242 }
243 function Resample(points, n)
244 {
245     var I = PathLength(points) / (n - 1); // interval length
246     var D = 0.0;
247     var newpoints = new Array(points[0]);
248     for (var i = 1; i < points.length; i++)
249     {
250         if (points[i].id == points[i-1].id)
251         {
252             var d = EuclideanDistance(points[i-1], points[i]);
253             if ((D + d) >= I)
254             {
255                 var qx = points[i-1].x + ((I - D) / d) * (points[i].x
256                     - points[i-1].x);
257                 var qy = points[i-1].y + ((I - D) / d) * (points[i].y
258                     - points[i-1].y);
259                 var qz = points[i-1].z + ((I - D) / d) * (points[i].z
260                     - points[i-1].z);
261                 var q = new Point(qx, qy, qz, points[i].id);
262                 newpoints[newpoints.length] = q; // append new point
263                 'q'
264                 points.splice(i, 0, q); // insert 'q' at position i
265                 in points s.t. 'q' will be the next i
266                 D = 0.0;
267             }
268         }
269     }

```



```

263     else D += d;
264 }
265 }
266 if (newpoints.length == n - 1) // sometimes we fall a
    rounding-error short of adding the last point, so add it
    if so
267     newpoints[newpoints.length] = new Point(points[points.
        length - 1].x, points[points.length - 1].y, points[
        points.length - 1].z, points[points.length - 1].id);
268 return newpoints;
269 }
270 function Scale(points)
271 {
272     var minX = +Infinity, maxX = -Infinity, minY = +Infinity,
        maxY = -Infinity, minZ = +Infinity, maxZ = -Infinity;
273     for (var i = 0; i < points.length; i++) {
274         minX = Math.min(minX, points[i].x);
275         minY = Math.min(minY, points[i].y);
276         minZ = Math.min(minZ, points[i].z);
277         maxX = Math.max(maxX, points[i].x);
278         maxY = Math.max(maxY, points[i].y);
279         maxZ = Math.max(maxZ, points[i].z);
280     }
281     var size = Math.max(maxX - minX, maxY - minY, maxZ - minZ);
282     var newpoints = new Array();
283     for (var i = 0; i < points.length; i++) {
284         var qx = (points[i].x - minX) / size;
285         var qy = (points[i].y - minY) / size;
286         var qz = (points[i].z - minZ) / size;
287         newpoints[newpoints.length] = new Point(qx, qy, qz,
            points[i].id);
288     }
289     return newpoints;
290 }
291 function TranslateTo(points, pt) // translates points'
    centroid to pt
292 {
293     var c = Centroid(points);
294     var newpoints = new Array();

```

```

295     for (var i = 0; i < points.length; i++) {
296         var qx = points[i].x + pt.x - c.x;
297         var qy = points[i].y + pt.y - c.y;
298         var qz = points[i].z + pt.z - c.z;
299         newpoints[newpoints.length] = new Point(qx, qy, qz,
300             points[i].id);
301     }
302     return newpoints;
303 }
304 function Centroid(points)
305 {
306     var x = 0.0, y = 0.0, z = 0.0;
307     for (var i = 0; i < points.length; i++) {
308         x += points[i].x;
309         y += points[i].y;
310         z += points[i].z;
311     }
312     x /= points.length;
313     y /= points.length;
314     z /= points.length;
315     return new Point(x, y, z, 0);
316 }
317 function PathLength(points) // length traversed by a point
318     path
319 {
320     var d = 0.0;
321     for (var i = 1; i < points.length; i++) {
322         if (points[i].id == points[i-1].id)
323             d += EuclideanDistance(points[i-1], points[i]);
324     }
325     return d;
326 }
327 function MakeIntCoords(points)
328 {
329     for (var i = 0; i < points.length; i++) {
330         points[i].intX = Math.round((points[i].x + 1.0) / 2.0 * (
331             MaxIntCoord - 1));
332         points[i].intY = Math.round((points[i].y + 1.0) / 2.0 * (
333             MaxIntCoord - 1));

```

```

330     points[i].intZ = Math.round((points[i].z + 1.0) / 2.0 * (
        MaxIntCoord - 1));
331 }
332 return points;
333 }
334 function ComputeLUT(points)
335 {
336     var LUT = new Array();
337     for (var i = 0; i < LUTSize; i++) {
338         LUT[i] = new Array();
339         for (var j = 0; j < LUTSize; j++) {
340             LUT[i][j] = new Array();
341         }
342     }
343
344     for (var x = 0; x < LUTSize; x++) {
345         for (var y = 0; y < LUTSize; y++) {
346             for (var z = 0; z < LUTSize; z++) {
347                 var u = -1;
348                 var b = +Infinity;
349                 for (var i = 0; i < points.length; i++) {
350                     var row = Math.round(points[i].intX /
                        LUTScaleFactor);
351                     var col = Math.round(points[i].intY /
                        LUTScaleFactor);
352                     var layer = Math.round(points[i].intZ /
                        LUTScaleFactor);
353                     var d = ((row - x) * (row - x)) + ((col - y) * (col
                        - y)) + ((layer - z) * (layer - z));
354                     if (d < b) {
355                         b = d;
356                         u = i;
357                     }
358                 }
359                 LUT[x][y][z] = u;
360             }
361         }
362     }
363     return LUT;

```

```

364 }
365 function SqrEuclideanDistance(pt1, pt2)
366 {
367     var dx = pt2.x - pt1.x;
368     var dy = pt2.y - pt1.y;
369     var dz = pt2.z - pt1.z;
370     return (dx * dx + dy * dy + dz * dz);
371 }
372 function EuclideanDistance(pt1, pt2)
373 {
374     var s = SqrEuclideanDistance(pt1, pt2);
375     return Math.sqrt(s);
376 }
377
378 module.exports = {
379     Recognizer
380 }

```

A.2.6 threecent-recognizer.js

```

1  const AbstractRecognizer = require('../../../../framework/
    recognizers/abstract-recognizer').AbstractRecognizer;
2  const math = require('mathjs');
3  const Spline = require('cubic-spline');
4
5
6  class Point {
7      constructor(x, y, z) {
8          this.x = x;
9          this.y = y;
10         this.z = z;
11     }
12 }
13
14
15 let NumPoints = 8;
16 let pathName;
17
18 class Recognizer extends AbstractRecognizer {

```

```

19
20     static name = "ThreeCentRecognizer";
21
22     constructor(options, dataset) {
23         super();
24         NumPoints = options.samplingPoints;
25         pathName = options.pathName;
26
27         this.templates = {};
28         this.threshold = Infinity;
29
30         if (dataset !== undefined){
31             dataset.getGestureClasses().forEach((gesture, key, self
32                 ) => {
33                 gesture.getSample().forEach(sample => {
34                     this.addGesture(gesture.name, sample);
35                 }
36             );
37         }
38     }
39
40
41     recognize(sample) {
42         let points = convert(sample);
43         let t0 = Date.now();
44         //
45         -----
46
47         points = normalizeP(points, NumPoints);
48
49         let bestFitClass = "";
50         //let minDist = this.threshold;
51         let minDist = Infinity;
52
53         // Compare gesture w/ each template
54         Object.keys(this.templates).forEach((name) => {
55             for (let i = 0; i < this.templates[name].length;
56                 i++) {

```

```

54         let tmpDist = gestureDistance(points, this.
           templates[name][i]);
55
56         if (tmpDist < minDist) {
57             minDist = tmpDist;
58             bestFitClass = name;
59         }
60     }
61 });
62
63     //
-----
64     let t1 = Date.now();
65     return (bestFitClass === "") ? { name: "", time: t1-t0, '
        Score': 0.0 } : { name: bestFitClass, time: t1-t0, '
        Score': minDist };
66 }
67
68
69     addGesture(name, sample) {
70         let points = convert(sample);
71         //
-----
72         points = normalizeP(points, NumPoints);
73
74         if (!this.templates.hasOwnProperty(name)) {
75             this.templates[name] = [];
76         }
77         this.templates[name].push(points);
78
79         //console.log(this.templates[name]);
80
81         let distances = new Array();
82
83         // For each class of gesture
84         Object.keys(this.templates).forEach((name) => {

```

```

85         // Compute the distance between each pair of
           gesture in the class, add it to distances
86     for (let i = 0; i < this.templates[name].length;
           i++) {
87         for (let k = i+1; k < this.templates[name].
           length; k++) {
88             distances.push(gestureDistance(this.
                templates[name][i], this.templates[
                name][k]));
89             //console.log(this.templates[name][i])
90         }
91     }
92 });
93
94 if (distances.length > 0) {
95     // Remove outliers and sort distances
96     //distances = rmOutliers(distances);
97     distances = distances.sort(function(a, b){return
        a - b});
98
99     // Histogram heuristic to compute decision
        distance threshold
100     var hist = histogram(distances, 30);
101     //console.log(hist["binWidth"])
102     var max = Math.max(...hist["values"]);
103     var indexMax = hist["values"].indexOf(max);
104     //console.log(max)
105     //console.log(indexMax)
106     var binWidth = hist["binWidth"];
107     var distancesHist = (((indexMax) * binWidth) + ((
        indexMax + 1) * binWidth)) / 2;
108     //console.log(distancesHist)
109     this.threshold = distancesHist;
110 }
111 }
112 }
113
114 function convert(sample) {
115     return sample.paths[pathName].strokes[0].points;

```

```

116 }
117
118 function histogram(data, numBins) {
119     let binWidth = math.round((math.max(data) / numBins) +
120         0.0005, 3);
121     let currentItemId = 0;
122     var bins = new Array(numBins).fill(0);
123     for (let i = 0; i < numBins; i++) {
124         while (currentItemId < math.size(data)[0] && (data[
125             currentItemId] < (i + 1) * binWidth || i ==
126             numBins - 1)) {
127             bins[i] += 1;
128             currentItemId += 1;
129         }
130     }
131     return { "values": bins, "binWidth": binWidth };
132 }
133
134 function gestureDistance(points1, points2) {
135     let dq = 0;
136
137     for (var i = 0; i < points1.length; i++) {
138         var dx = points1[i].x - points2[i].x;
139         var dy = points1[i].y - points2[i].y;
140         var dz = points1[i].z - points2[i].z;
141         dq += dx * dx + dy * dy + dz * dz;
142     }
143
144     return dq;
145 }
146
147 // -----
148
149 function normalizeP(points, n) {
150     let dist = [0];
151     for (let i = 1; i < points.length; i++) {
152         dx = points[i].x - points[i-1].x;
153         dy = points[i].y - points[i-1].y;

```



```

152         dz = points[i].z - points[i-1].z;
153         dist.push(Math.sqrt(dx * dx + dy * dy + dz * dz));
154     }
155
156     var s = cumsum(dist);
157     var len = s[s.length - 1];
158
159     // Resample
160     let h = (points.length-1) / (n - 1);
161     let xq = math.range(0, points.length - 1, h)._data;
162     xq.push(points.length - 1);
163
164     let x = [];
165     let xAxis = [];
166     let yAxis = [];
167     let zAxis = [];
168
169     for (let i = 0; i < points.length; i++) {
170         x.push(i);
171         xAxis.push(points[i].x);
172         yAxis.push(points[i].y);
173         zAxis.push(points[i].z);
174     }
175
176     let sX = spline(x, xAxis, xq);
177     let sY = spline(x, yAxis, xq);
178     let sZ = spline(x, zAxis, xq);
179
180     let avgX = sX.reduce((a,b) => a + b, 0) / sX.length;
181     let avgY = sY.reduce((a,b) => a + b, 0) / sY.length;
182     let avgZ = sZ.reduce((a,b) => a + b, 0) / sZ.length;
183
184     let newPoints = [];
185     for (let i = 0; i < xq.length; i++) {
186         // Center (wrt. centroid) and scale
187         newPoints.push(new Point((sX[i] - avgX) / len, (sY[i]
188             - avgY) / len, (sZ[i] - avgZ) / len));
189     }

```

```

190     return newPoints;
191 }
192
193 function cumsum(data) {
194     var acc = 0;
195     return math.map(data, function(x) {
196         acc += x;
197         return acc;
198     })
199 }
200
201 // cubic interpolation of x and y.
202 // xq: query points
203 function spline(x, y, xq) {
204     const spline = new Spline(x, y);
205     var s = new Array(xq.length);
206     for (let i = 0; i < xq.length; i++) {
207         s[i] = spline.at(xq[i]);
208     }
209     return s;
210 }
211
212
213 module.exports = {
214     Recognizer
215 };

```

A.3 DatasetLoaders

A.3.1 guinevereDatasetLoader.js

```

1 const fs = require('fs');
2 const path = require('path');
3
4 const GestureSet = require('../framework/gestures/gesture-
    set').GestureSet;
5 const GestureClass = require('../framework/gestures/
    gesture-class').GestureClass;

```

```

6 const StrokeData = require('../../framework/gestures/stroke-
  data').StrokeData;
7 const Stroke = require('../../framework/gestures/stroke-data')
  .Stroke;
8 const Path = require('../../framework/gestures/stroke-data').
  Path;
9 const Point = require('../../framework/gestures/point').
  Point3D;
10 const UnifiedDatasetLoader = require('../../framework/
  datasets/UnifiedDatasetLoader');
11
12 const palms = ["rightPalmPosition", "leftPalmPosition"];
13 const fingers = ["rightThumbPosition", "rightIndexPosition",
  "rightMiddlePosition", "rightRingPosition", "
  rightPinkyPosition", "leftThumbPosition", "
  leftIndexPosition", "leftMiddlePosition", "
  leftRingPosition", "leftPinkyPosition"];
14
15 const device = {
16   'osBrowserInfo': 'Leap Motion Controller', '
    resolutionHeight': null,
17   'resolutionWidth': null, 'windowHeight': null, '
    windowWidth': null,
18   'pixelRatio': null, 'mouse': false, 'pen': false, 'finger
    ': false,
19   'acceleration': false, 'webcam': true
20 };
21
22 function loadDataset(name, directory) {
23   let gestureSet = new GestureSet(name);
24   let dirPath = path.join(directory, name);
25   let gestureIndex = 0;
26   fs.readdirSync(dirPath).forEach((user_dir) => {
27     let gestureSampleDirPath = path.join(dirPath,
      user_dir);
28     fs.readdirSync(gestureSampleDirPath).forEach((sample)
      => {
29       let rawGesturePath = path.join(
        gestureSampleDirPath, sample);

```

```

30     let rawGestureData = JSON.parse(fs.readFileSync(
31         rawGesturePath));
32
33     let filename = sample.split(".")[0].split("-");
34     let gestureName = filename[0].split("#")[0];
35     let infosupp = undefined;
36     if (filename[0].split("#").length > 1) {
37         infosupp = filename[0].split("#")[1];
38     }
39     let id = filename[1];
40
41     let gestureData = new StrokeData(parseInt(
42         user_dir), id, infosupp);
43     if (gestureSet.getGestureClasses().has(
44         gestureName)) {
45         gestureSet.getGestureClasses().get(
46             gestureName).addSample(gestureData);
47     } else {
48         let gestureClass = new GestureClass(
49             gestureName, gestureIndex);
50         gestureIndex += 1;
51         gestureClass.addSample(gestureData);
52         gestureSet.addGestureClass(gestureClass);
53     }
54
55     // Init stroke paths
56     fingers.forEach((fingerName) => {
57         let strokePath = new Path(fingerName);
58         gestureData.addPath(fingerName, strokePath);
59         let stroke = new Stroke(0);
60         strokePath.addStroke(stroke);
61     });
62     for (const palm of palms) {
63         let strokePath = new Path(palm);
64         gestureData.addPath(palm, strokePath);
65         let stroke = new Stroke(0);
66         strokePath.addStroke(stroke);
67     }

```

```

64
65     for (let i = 0; i < rawGestureData['data'].length
66         ; i++) {
67         let frame = rawGestureData['data'][i];
68
69         let points = {};
70         for (const palm of palms) {
71             points[palm] = null;
72         }
73         for (const finger of fingers) {
74             points[finger] = null;
75         }
76
77         let rightHandId = -1;
78         let leftHandId = -1;
79         for (const hand of frame['hands']) {
80             let palmName;
81             if (hand['type'] === 'right') {
82                 rightHandId = hand['id'];
83                 palmName = "rightPalmPosition";
84             }
85             else {
86                 leftHandId = hand['id'];
87                 palmName = "leftPalmPosition";
88             }
89             let palmPosition = hand['palmPosition'];
90             points[palmName] = new Point(palmPosition
91                 [0], palmPosition[1], palmPosition[2],
92                 frame['timestamp']);
93         }
94
95         for (const pointable of frame['pointables'])
96         {
97             if (!pointable.tool) {
98                 // Get the name of the finger from
99                 // handId and type
100                 let fingerName = getFingerName(
101                     pointable.handId == rightHandId,
102                     pointable.type);

```

```

96         let tipPosition = pointable['
           tipPosition'];
97         points[fingerName] = new Point(
           tipPosition[0], tipPosition[1],
           tipPosition[2], frame['timestamp'
           ]);
98     }
99 }
100
101 // Add points to paths (with default point w/
   coordinates (x=0, y=0, z=0))
102 Object.keys(points).forEach((articulation) =>
   {
103     let stroke = gestureData.paths[
       articulation].strokes[0];
104     if (points[articulation] === null) {
105         // Default coordinates
106         stroke.addPoint(new Point(0, 0, 0,
           frame['timestamp']));
107     } else {
108         // Coordinates from frame
109         stroke.addPoint(points[articulation])
           ;
110     }
111 });
112 }
113 });
114 });
115 return gestureSet;
116 }
117
118 function getFingerName(isRight, type) {
119     if (isRight) {
120         return fingers[type];
121     } else {
122         return fingers[5 + type];
123     }
124 }
125

```

```

126
127 if (require.main === module) {
128     const dirPath = path.join(__dirname, '../../datasets');
129     const convertedPath = path.join(__dirname, '../../
        datasets', 'guinevere_unified');
130
131     let dataset = loadDataset("guinevere", dirPath);
132     UnifiedDatasetLoader.writeDataset(dataset, convertedPath)
        ;
133 }

```

A.3.2 HandGestureCsvDatasetLoader.js

```

1 const path = require('path');
2 const fs = require('fs');
3
4 const GestureSet = require('../../framework/gestures/gesture-
    set').GestureSet;
5 const GestureClass = require('../../framework/gestures/
    gesture-class').GestureClass;
6 const StrokeData = require('../../framework/gestures/stroke-
    data').StrokeData;
7 const Stroke = require('../../framework/gestures/stroke-data')
    .Stroke;
8 const Path = require('../../framework/gestures/stroke-data').
    Path;
9 const Point = require('../../framework/gestures/point').
    Point3D;
10
11 //const gestureNames = ["Tap", "Swipe Right", "Swipe Left", "
    Swipe Up", "Swipe Down", "Swipe X", "Swipe +", "Swipe V",
    "Shake"];
12 const gestureNames = ["Grab", "Tap", "Expand", "Pinch", "
    Rotation Clockwise", "Rotation Counter Clockwise",
13     "Swipe Right", "Swipe Left", "Swipe Up", "Swipe Down", "
    Swipe X", "Swipe +", "Swipe V", "Shake"];
14
15 function loadDataset(name, directory) {
16     let gestureSet = new GestureSet(name);

```

```

17     let dirPath = path.join(directory, name);
18     let gestureIndex = 0;
19
20     fs.readdirSync(dirPath).forEach((dir) => {
21         let gestureClassDirPath = path.join(dirPath, dir);
22         var stat = fs.lstatSync(gestureClassDirPath);
23         if (!stat.isDirectory())
24             return;
25         gestureClassDirPath = path.join(gestureClassDirPath,
26             "finger_1");
27         let gestureClass = new GestureClass(gestureNames[
28             gestureIndex], gestureIndex);
29         gestureIndex+=1;
30         fs.readdirSync(gestureClassDirPath).forEach((file) =>
31             {
32                 let rawGesturePath = path.join(
33                     gestureClassDirPath, file);
34                 let filename = file.split(".")[0].split("_");
35                 let lines = fs.readFileSync(rawGesturePath, 'utf
36                     -8').split(/\r?\n/);
37                 lines = lines.slice(1, lines.length - 1); //
38                     remove header and last line
39                 let gestureData = new StrokeData(parseInt(
40                     filename[1]), parseInt(filename[3]));
41                 let strokePath = new Path("main");
42                 gestureData.addPath("main", strokePath);
43                 let stroke = new Stroke(0);
44
45                 lines.forEach(line =>{
46                     line = line.split(",");
47                     //index tip
48                     let x = parseFloat(line[27]);
49                     let y = parseFloat(line[28]);
50                     let z = parseFloat(line[29]);
51                     let t = 0;
52                     stroke.addPoint(new Point(x, y, z, t));
53                 });
54
55                 strokePath.addStroke(stroke);

```



```

49         gestureClass.addSample(gestureData);
50
51     });
52
53     gestureSet.addGestureClass(gestureClass);
54 });
55
56     return gestureSet;
57 }
58
59 module.exports = {
60     loadDataset
61 };

```

A.3.3 LeapmotionDatasetLoader.js

```

1  const path = require('path');
2  const fs = require('fs');
3
4  const GestureSet = require('.../framework/gestures/gesture-
    set').GestureSet;
5  const GestureClass = require('.../framework/gestures/
    gesture-class').GestureClass;
6  const StrokeData = require('.../framework/gestures/stroke-
    data').StrokeData;
7  const Stroke = require('.../framework/gestures/stroke-data'
    ).Stroke;
8  const Path = require('.../framework/gestures/stroke-data').
    Path;
9  const Point = require('.../framework/gestures/point').
    Point3D;
10
11 const palms = ["rightPalmPosition", "leftPalmPosition"];
12 const fingers = ["rightThumbPosition", "rightIndexPosition",
    "rightMiddlePosition", "rightRingPosition", "
    rightPinkyPosition", "leftThumbPosition", "
    leftIndexPosition", "leftMiddlePosition", "
    leftRingPosition", "leftPinkyPosition"];
13

```

```

14
15 function loadDataset(name, directory) {
16     let gestureSet = new GestureSet(name);
17     let dirPath = path.join(directory, name);
18     let gestureIndex = 0;
19
20     fs.readdirSync(dirPath).forEach((dir) => {
21         let gestureClassDirPath = path.join(dirPath, dir);
22         let gestureClass = new GestureClass(dir, gestureIndex
23             );
24         gestureIndex+=1;
25         fs.readdirSync(gestureClassDirPath).forEach((sample)
26             => {
27             let rawGesturePath = path.join(
28                 gestureClassDirPath, sample);
29             let rawGestureData = JSON.parse(fs.readFileSync(
30                 rawGesturePath));
31             let filename = sample.split(".")[0].split("-");
32             let gestureData = new StrokeData(parseInt(
33                 filename[1]), parseInt(filename[2]));
34             gestureClass.addSample(gestureData);
35
36             // Init stroke paths
37             fingers.forEach((fingerName) => {
38                 let strokePath = new Path(fingerName);
39                 gestureData.addPath(fingerName, strokePath);
40                 let stroke = new Stroke(0);
41                 strokePath.addStroke(stroke);
42             });
43             for (const palm of palms) {
44                 let strokePath = new Path(palm);
45                 gestureData.addPath(palm, strokePath);
46                 let stroke = new Stroke(0);
47                 strokePath.addStroke(stroke);
48             }
49
50             for (let i = 0; i < rawGestureData['data'].length
51                 ; i++) {

```

```

47         let frame = rawGestureData['data'][i];
48
49         let points = {};
50         for (const palm of palms) {
51             points[palm] = null;
52         }
53         for (const finger of fingers) {
54             points[finger] = null;
55         }
56
57         let rightHandId = -1;
58         let leftHandId = -1;
59         for (const hand of frame['hands']) {
60             let palmName;
61             if (hand['type'] === 'right') {
62                 rightHandId = hand['id'];
63                 palmName = "rightPalmPosition";
64             }
65             else {
66                 leftHandId = hand['id'];
67                 palmName = "leftPalmPosition";
68             }
69             let palmPosition = hand['palmPosition'];
70             points[palmName] = new Point(palmPosition
              [0], palmPosition[1], palmPosition[2],
              frame['timestamp']);
71         }
72
73         for (const pointable of frame['pointables'])
74         {
75             if (!pointable.tool) {
76                 // Get the name of the finger from
77                 // handId and type
78                 let fingerName = getFingerName(
79                     pointable.handId == rightHandId,
80                     pointable.type);
81                 let tipPosition = pointable['
82                     tipPosition'];

```

```

78         points[fingerName] = new Point(
            tipPosition[0], tipPosition[1],
            tipPosition[2], frame['timestamp'
            ]);
79     }
80 }
81
82 // Add points to paths (with default point w/
    coordinates (x=0, y=0, z=0))
83 Object.keys(points).forEach((articulation) =>
    {
84     let stroke = gestureData.paths[
        articulation].strokes[0];
85     if (points[articulation] === null) {
86         // Default coordinates
87         stroke.addPoint(new Point(0, 0, 0,
            frame['timestamp']));
88     } else {
89         // Coordinates from frame
90         stroke.addPoint(points[articulation])
            ;
91     }
92 });
93 }
94
95 });
96
97 gestureSet.addGestureClass(gestureClass);
98 });
99
100 return gestureSet;
101 }
102
103 function getFingerName(isRight, type) {
104     if (isRight) {
105         return fingers[type];
106     } else {
107         return fingers[5 + type];
108     }

```

```

109 }
110
111 module.exports = {
112     loadDataset
113 };

```

A.3.4 SmartphoneDatasetLoader.js

```

1  const path = require('path');
2  const fs = require('fs');
3
4  const GestureSet = require('../framework/gestures/gesture-
    set').GestureSet;
5  const GestureClass = require('../framework/gestures/
    gesture-class').GestureClass;
6  const StrokeData = require('../framework/gestures/stroke-
    data').StrokeData;
7  const Stroke = require('../framework/gestures/stroke-data'
    ).Stroke;
8  const Path = require('../framework/gestures/stroke-data').
    Path;
9  const Point = require('../framework/gestures/point').
    Point2D;
10
11
12  function loadDataset(name, directory) {
13      let gestureSet = new GestureSet(name);
14      let dirPath = path.join(directory, name);
15      let gestureIndex = 0;
16
17      fs.readdirSync(dirPath).forEach((dir) => {
18          let gestureClassDirPath = path.join(dirPath, dir);
19          let gestureClass = new GestureClass(dir, gestureIndex
              );
20          gestureIndex+=1;
21
22          fs.readdirSync(gestureClassDirPath).forEach((file) =>
              {

```

```

23         let rawGesturePath = path.join(
24             gestureClassDirPath, file);
25         let rawGestureData = JSON.parse(fs.readFileSync(
26             rawGesturePath));
27         let gestureData = new StrokeData();
28         let strokePath = new Path("main");
29         gestureData.addPath("main", strokePath);
30
31         for(let i = 0 ; i < rawGestureData[0].strokes.
32             length ; i++) {
33             let stroke = new Stroke(i);
34             for(var j = 0 ; j < rawGestureData[0].strokes
35                 [i].length ; j++) {
36                 let x = rawGestureData[0].strokes[i][j].x
37                     ;
38                 let y = rawGestureData[0].strokes[i][j].y
39                     ;
40                 let t = rawGestureData[0].strokes[i][j].t
41                     ;
42                 stroke.addPoint(new Point(x,y,t));
43             }
44             strokePath.addStroke(stroke);
45         }
46         gestureClass.addSample(gestureData)
47     });
48
49     gestureSet.addGestureClass(gestureClass)
50 });
51
52     return gestureSet;
53 }
54
55 module.exports = {
56     loadDataset
57 };

```

A.3.5 uWaveDatasetLoader.js

```

1 const path = require('path');

```

```

2  const fs = require('fs');
3
4  const GestureSet = require('../../framework/gestures/gesture-
    set').GestureSet;
5  const GestureClass = require('../../framework/gestures/
    gesture-class').GestureClass;
6  const StrokeData = require('../../framework/gestures/stroke-
    data').StrokeData;
7  const Stroke = require('../../framework/gestures/stroke-data'
    ).Stroke;
8  const Path = require('../../framework/gestures/stroke-data').
    Path;
9  const Point = require('../../framework/gestures/point').
    Point3D;
10
11
12  function loadDataset(name, directory) {
13      let gestureSet = new GestureSet(name);
14      let dirPath = path.join(directory, name);
15
16      let gestureClasses = {};
17
18      // Browse main directory
19      fs.readdirSync(dirPath).forEach((dir) => {
20          let gestureClassDirPath = path.join(dirPath, dir);
21          // Subdirectories
22          fs.readdirSync(gestureClassDirPath).forEach((file) =>
23              {
24                  let rawGesturePath = path.join(
25                      gestureClassDirPath, file);
26                  let lines = fs.readFileSync(rawGesturePath, 'utf
27                      -8').split(/\r?\n/);
28                  let gestureData = new StrokeData();
29                  let strokePath = new Path("main");
30                  let stroke = new Stroke(0);
31                  strokePath.addStroke(stroke);
32
33                  let gestureId = file.slice(23, 24);

```

```

32         let index = 0;
33         for (const line of lines) {
34             let data = line.split(' ');
35             if(data.length == 3) {
36                 let x = parseFloat(data[0]);
37                 let y = parseFloat(data[1]);
38                 let z = parseFloat(data[2]);
39                 let t = index++;
40                 stroke.addPoint(new Point(x, y, z, t));
41             }
42         }
43
44         if (index < 10) {
45             // Ignore, probably bad data
46             console.log('Too few datapoints (${index}) -
47                 ${rawGesturePath}');
48         } else {
49             gestureData.addPath("main", strokePath);
50             if (!gestureClasses.hasOwnProperty(gestureId)
51                 ) {
52                 gestureClasses[gestureId] = new
53                     GestureClass('Gesture ${gestureId}');
54             }
55             gestureClasses[gestureId].addSample(
56                 gestureData);
57         }
58     });
59 })
60
61 Object.keys(gestureClasses).forEach((key) => {
62     gestureSet.addGestureClass(gestureClasses[key]);
63 });
64
65 return gestureSet;
66 }
67
68 module.exports = {
69     loadDataset
70 };

```


A.4 Segmenters

A.4.1 lefthand-segmenter.js

```
1 const AbstractSegmenter = require('../..//framework/segmenters
  /abstract-segmenter').AbstractSegmenter;
2 const StrokeData = require('../..//framework/gestures/stroke-
  data').StrokeData;
3 const Stroke = require('../..//framework/gestures/stroke-data'
  ).Stroke;
4 const Path = require('../..//framework/gestures/stroke-data').
  Path;
5 const Point = require('../..//framework/gestures/point').
  Point3D;
6
7 class Segmenter extends AbstractSegmenter {
8   constructor(options) {
9     super(options);
10    this.minFrames = options.minSegmentLength;
11    this.maxFrames = options.maxSegmentLength;
12    this.strokeData = null;
13    this.frameCount = 0;
14  }
15
16  segment(frame) {
17    if (frame.hasLeftHand) {
18      if (this.frameCount >= this.maxFrames) {
19        // Max number of frames reached
20        let oldStrokeData = this.strokeData;
21        this.strokeData = null;
22        this.frameCount = 0;
23        return oldStrokeData;
24      }
25      if (this.strokeData === null) {
26        // Initialize strokeData
27        this.strokeData = new StrokeData();
28        for (const articulation of frame.
          articulations) {
29          let path = new Path(articulation.label);
```

```

30         this.strokeData.addPath(articulation.
31             label, path);
32         let stroke = new Stroke();
33         path.addStroke(stroke);
34         // Quick hack to remove left hand
35         if (articulation.label.includes("left"))
36         {
37             stroke.addPoint(new Point(0, 0, 0,
38                 frame.timestamp));
39         } else {
40             stroke.addPoint(articulation.point);
41         }
42     }
43     } else {
44         for (const articulation of frame.
45             articulations) {
46             let path = this.strokeData.paths[
47                 articulation.label];
48             let stroke = path.strokes[0];
49             // Quick hack to remove left hand
50             if (articulation.label.includes("left"))
51             {
52                 stroke.addPoint(new Point(0, 0, 0,
53                     frame.timestamp));
54             } else {
55                 stroke.addPoint(articulation.point);
56             }
57         }
58     }
59     this.frameCount++;
60 } else if (this.frameCount > this.minFrames) {
61     // Left hand removed and enough frames
62     let oldStrokeData = this.strokeData;
63     this.strokeData = null;
64     this.frameCount = 0;
65     return oldStrokeData;
66 } else {
67     // Left hand removed and not enough frames
68     this.strokeData = null;

```

```

62         this.frameCount = 0;
63     }
64     return null;
65 }
66
67     notifyRecognition() {
68         // Do nothing
69     }
70 }
71
72 module.exports = {
73     Segmenter
74 };

```

A.4.2 window-segmenter.js

```

1  const AbstractSegmenter = require('../framework/segmenters
    /abstract-segmenter').AbstractSegmenter;
2  const StrokeData = require('../framework/gestures/stroke-
    data').StrokeData;
3  const Stroke = require('../framework/gestures/stroke-data'
    ).Stroke;
4  const Path = require('../framework/gestures/stroke-data').
    Path;
5
6  class Segmenter extends AbstractSegmenter {
7
8      constructor(options) {
9          super(options);
10         this.windowWidth = options.windowWidth;
11         this.numberIntervalFrames = options.intervallLength;
12         this.numberPauseFrames = options.pauseLength;
13         this.frameBuffer = null;
14         this.intervalCount = 0;
15         this.pauseCount = 0;
16         this.bufferLength = 0;
17     }
18
19     segment(frame) {

```

```

20     if (this.frameBuffer === null) {
21         // Initialize frameBuffer
22         this.frameBuffer = initBuffer(frame);
23     } else {
24         for (const articulation of frame.articulations) {
25             this.frameBuffer[articulation.label].push(
26                 articulation.point);
27             if (this.bufferLength >= this.windowWidth) {
28                 // Shift items in buffer
29                 this.frameBuffer[articulation.label].
30                     shift();
31             }
32         }
33         // Increment pause count
34         this.pauseCount = Math.max(this.pauseCount - 1, 0);
35         this.intervalCount = (this.intervalCount + 1) % this.
36             numberIntervalFrames;
37         if (this.bufferLength < this.windowWidth) {
38             // Buffer not full
39             this.bufferLength++;
40             return null;
41         } else if (this.pauseCount == 0 && this.intervalCount
42             == 0 && (frame.hasLeftHand || frame.hasRightHand)
43         ) {
44             let strokeData = new StrokeData();
45             // Buffer full & ready
46             for (const articulation of frame.articulations) {
47                 let path = new Path(articulation.label);
48                 strokeData.addPath(articulation.label, path);
49                 let stroke = new Stroke();
50                 path.addStroke(stroke)
51                 stroke.points = this.frameBuffer[articulation
52                     .label].slice();
53             }
54             return strokeData;
55         } else {
56             // Pause
57             return null;

```

```

53     }
54 }
55
56   notifyRecognition() {
57     this.pauseCount = this.numberPauseFrames;
58   }
59 }
60
61 function initBuffer(frame) {
62   let buffer = {};
63   for (const articulation of frame.articulations) {
64     buffer[articulation.label] = [ articulation.point ];
65   }
66   return buffer;
67 }
68
69 module.exports = {
70   Segmenter
71 };

```

A.4.3 zoning-segmenter.js

```

1 const AbstractSegmenter = require('../framework/segmenters
  /abstract-segmenter').AbstractSegmenter;
2 const StrokeData = require('../framework/gestures/stroke-
  data').StrokeData;
3 const Stroke = require('../framework/gestures/stroke-data'
  ).Stroke;
4 const Path = require('../framework/gestures/stroke-data').
  Path;
5
6 const xBound = 120;
7 const zBound = 60;
8
9 class Segmenter extends AbstractSegmenter {
10   constructor(options) {
11     super(options);
12     this.minFrames = options.minSegmentLength;
13     this.maxFrames = options.maxSegmentLength;

```

```

14     this.numberPauseFrames = options.pauseLength;
15     this.strokeData = null;
16     this.pauseCount = 0;
17 }
18
19 segment(frame) {
20     // Increment pause count
21     this.pauseCount = Math.max(this.pauseCount - 1, 0);
22     if (this.pauseCount !== 0) {
23         return null;
24     }
25     if (isWithinBounds(frame)) {
26         // At least one hand is in the zone
27         if (this.frameCount >= this.maxFrames) {
28             // Max number of frames reached
29             let oldStrokeData = this.strokeData;
30             this.strokeData = null;
31             this.frameCount = 0;
32             return oldStrokeData;
33         }
34         if (this.strokeData === null) {
35             // Initialize strokeData
36             this.strokeData = new StrokeData();
37             for (const articulation of frame.
38                 articulations) {
39                 let path = new Path(articulation.label);
40                 this.strokeData.addPath(articulation.
41                     label, path);
42                 let stroke = new Stroke();
43                 path.addStroke(stroke);
44                 stroke.addPoint(articulation.point);
45             }
46         } else {
47             for (const articulation of frame.
48                 articulations) {
49                 let path = this.strokeData.paths[
50                     articulation.label];
51                 let stroke = path.strokes[0];
52                 stroke.addPoint(articulation.point);

```

```

49         }
50     }
51     this.frameCount++;
52 } else if (this.frameCount > this.minFrames) {
53     // Hands outside of the zone & enough frames
54     let oldStrokeData = this.strokeData;
55     this.strokeData = null;
56     this.frameCount = 0;
57     return oldStrokeData;
58 } else {
59     // Hands outside of the zone and not enough
        frames
60     this.strokeData = null;
61     this.frameCount = 0;
62 }
63 return null;
64 }
65
66 notifyRecognition() {
67     this.pauseCount = this.numberPauseFrames;
68 }
69 }
70
71 function isWithinBounds(frame) {
72     let withinBounds = false;
73     if (frame.hasLeftHand) {
74         let x = frame.getArticulation("leftPalmPosition").
            point.x;
75         let z = frame.getArticulation("leftPalmPosition").
            point.z;
76         withinBounds = x < xBound && x > -xBound && z <
            zBound && z > -zBound;
77     }
78     if (!withinBounds && frame.hasRightHand) {
79         let x = frame.getArticulation("rightPalmPosition").
            point.x;
80         let z = frame.getArticulation("rightPalmPosition").
            point.z;

```

```

81         withinBounds = x < xBound && x > -xBound && z <
            zBound && z > -zBound;
82     }
83     return withinBounds;
84 }
85
86 module.exports = {
87     Segmenter
88 };

```

A.5 DICOM viewer

A.5.1 index.js

```

1  import React from "react";
2  import { render } from "react-dom";
3  import CornerstoneElement from "../components/
    CornerstoneElement";
4
5  const stack = {
6      imageIds: [],
7      currentStudiesIdIndex: 0,
8      currentImageIdIndex: 0
9  };
10
11
12  class App extends React.Component {
13
14      render() {
15          return (
16              <div>
17                  <CornerstoneElement stack={{ ...stack }}/>
18              </div>
19          );
20      }
21  }
22
23  render(<App />, document.getElementById("root"));

```


A.5.2 proxy.js

```
1 var http = require('http'),
2     httpProxy = require('http-proxy');
3
4 var proxy = httpProxy.createProxyServer({target:'http://
    localhost:8042'}).listen(8000);
5
6 proxy.on('proxyRes', function(proxyReq, req, res, options) {
7     // add the CORS header to the response
8     res.setHeader('Access-Control-Allow-Origin', '*');
9 });
10
11 proxy.on('error', function(e) {
12     // suppress errors
13 });
14
15 console.log("\t Running...");
```

A.5.3 CornerstoneElement.js

```
1 import React from "react";
2 import * as cornerstone from "cornerstone-core";
3 import * as cornerstoneWADOImageLoader from "cornerstone-wado
    -image-loader";
4 import * as dicomParser from "dicom-parser";
5 import GestureHandler from "../gesturehandler";
6 import axios from 'axios' // we use this library as HTTP
    client
7
8
9 cornerstoneWADOImageLoader.external.cornerstone = cornerstone
    ;
10 cornerstoneWADOImageLoader.external.dicomParser = dicomParser
    ;
11
12 const PACS_url = "http://localhost:8000";
13 const studiesId = "6b9e19d9-62094390-5f9ddb01-4a191ae7-9766
    b715";
14
```

```

15 const divStyle = {
16     width: "100%",
17     height: (window.innerHeight - 20).toString() + "px",
18     position: "relative",
19     color: "white"
20 };
21
22 const bottomLeftStyle = {
23     bottom: "5px",
24     left: "5px",
25     position: "absolute",
26     color: "white"
27 };
28
29 const bottomRightStyle = {
30     bottom: "5px",
31     right: "5px",
32     position: "absolute",
33     color: "white"
34 };
35
36 const bottomCenterStyle = {
37     bottom: "5px",
38     position: "absolute",
39     color: "white",
40     width: '100%',
41     textAlign: 'center'
42 };
43
44 class CornerstoneElement extends React.Component {
45     constructor(props) {
46         super(props);
47         this.state = {
48             stack: props.stack,
49             viewport: cornerstone.getDefaultViewport(null,
50                 undefined),
51             imageId: props.stack.imageIds[0],
52             series: [],
53             instances: [[]]

```

```

53     };
54     this.onImageRendered = this.onImageRendered.bind(this
55     );
56     this.onNewImage = this.onNewImage.bind(this);
57     this.onWindowResize = this.onWindowResize.bind(this);
58 }
59 render() {
60     return (
61         <div>
62             <div
63                 className="viewportElement"
64                 style={divStyle}
65                 ref={input => {
66                     this.element = input;
67                 }}
68             >
69                 <canvas className="cornerstone-canvas"/>
70                 <div style={bottomLeftStyle}>Zoom: {this.
71                     state.viewport.scale}</div>
72                 <div style={bottomRightStyle}>
73                     WW/WC: {this.state.viewport.voi.
74                         windowWidth} /{" "}
75                     {this.state.viewport.voi.windowCenter
76                         }
77                 </div>
78                 <div style={bottomCenterStyle}>
79                     Image: {this.state.stack.
80                         currentImageIdIndex + 1} /{" "}
81                     {this.state.instances[this.state.
82                         stack.currentStudiesIdIndex].
83                         length}
84                 </div>
85             </div>
86         </div>
87     );
88 }
89
90 pan(direction) {

```

```

85     const viewport = cornerstone.getViewport(this.element
86         );
87     let translation = {x: 0, y: 0};
88     let offset = 10;
89     switch (direction) {
90         case "up":
91             translation.y += offset;
92             break;
93         case "down":
94             translation.y -= offset;
95             break;
96         case "left":
97             translation.x += offset;
98             break;
99         case "right":
100             translation.x -= offset;
101             break;
102         default:
103             break;
104     }
105     viewport.translation.x += translation.x;
106     viewport.translation.y += translation.y;
107     cornerstone.setViewport(this.element, viewport);
108 }
109
110 zoom(direction) {
111     const viewport = cornerstone.getViewport(this.element
112         );
113     let scale = viewport.scale;
114     let offset = 0.1;
115     switch (direction) {
116         case "in":
117             scale += offset;
118             break;
119         case "out":
120             scale -= offset;
121             break;
122         default:
123             break;

```

```

122     }
123     viewport.scale = scale;
124     cornerstone.setViewport(this.element, viewport);
125 }
126
127 rotate(direction) {
128     const viewport = cornerstone.getViewport(this.element
129         );
130     let rotation = viewport.rotation;
131     let offset = 90;
132     switch (direction) {
133         case "cw":
134             rotation += offset;
135             break;
136         case "ccw":
137             rotation -= offset;
138             break;
139         default:
140             break;
141     }
142     viewport.rotation = rotation;
143     cornerstone.setViewport(this.element, viewport);
144 }
145
146 contrast(direction) {
147     const viewport = cornerstone.getViewport(this.element
148         );
149     let windowWidth = viewport.voi.windowWidth;
150     let offset = 50;
151     switch (direction) {
152         case "inc":
153             windowWidth += offset;
154             break;
155         case "dec":
156             windowWidth -= offset;
157             break;
158         default:
159             break;
160     }

```

```

159     viewport.voi.windowWidth = windowWidth;
160     cornerstone.setViewport(this.element, viewport);
161 }
162
163 nextFrame() {
164     let next_stack = Object.assign({}, this.state.stack);
165     let next_instance = (next_stack.currentImageIdIndex +
166         1) % this.state.instances[next_stack.
167             currentStudiesIdIndex].length;
168     next_stack.currentImageIdIndex = next_instance;
169     this.setState({
170         stack: next_stack
171     });
172     let nextImage = this.state.instances[next_stack.
173         currentStudiesIdIndex][next_instance];
174     this.setImage(nextImage, this.element);
175 }
176
177 previousFrame() {
178     let next_stack = Object.assign({}, this.state.stack);
179     let len = this.state.instances[next_stack.
180         currentStudiesIdIndex].length;
181     let next_instance = (len + next_stack.
182         currentImageIdIndex - 1) % len;
183     next_stack.currentImageIdIndex = next_instance;
184     this.setState({
185         stack: next_stack
186     });
187     let nextImage = this.state.instances[next_stack.
188         currentStudiesIdIndex][next_instance];
189     this.setImage(nextImage, this.element);
190 }
191
192 nextStudy() {
193     let next_stack = Object.assign({}, this.state.stack);
194     let next_study = (next_stack.currentStudiesIdIndex +
195         1) % this.state.instances.length;
196     next_stack.currentStudiesIdIndex = next_study;
197     next_stack.currentImageIdIndex = 0;

```

```

191     this.setState({
192         stack: next_stack
193     });
194     let nextImage = this.state.instances[next_study][0];
195     this.resetImage(nextImage, this.element);
196 }
197
198 previousStudy() {
199     const element = this.element;
200     let next_stack = Object.assign({}, this.state.stack);
201     let len = this.state.instances.length;
202     let next_study = (len + next_stack.
        currentStudiesIdIndex - 1) % len;
203     next_stack.currentStudiesIdIndex = next_study;
204     next_stack.currentImageIdIndex = 0;
205     this.setState({
206         stack: next_stack
207     });
208     let nextImage = this.state.instances[next_study][0];
209     this.resetImage(nextImage, element);
210 }
211
212 onKeyPress = (event) => {
213     if (event.preventDefault) {
214         return; // Do nothing if event already handled
215     }
216
217     switch (event.code) {
218         case "KeyS":
219             this.pan("down");
220             break;
221         case "KeyW":
222             this.pan("up");
223             break;
224         case "KeyA":
225             this.pan("left");
226             break;
227         case "KeyD":
228             this.pan("right");

```

```

229         break;
230     case "KeyZ":
231         this.zoom("in");
232         break;
233     case "KeyX":
234         this.zoom("out");
235         break;
236     case "KeyC":
237         this.rotate("cw");
238         break;
239     case "KeyV":
240         this.rotate("ccw");
241         break;
242     case "KeyM":
243         this.contrast("inc");
244         break;
245     case "KeyN":
246         this.contrast("dec");
247         break;
248     case "ArrowDown":
249         this.previousStudy();
250         break;
251     case "ArrowUp":
252         this.nextStudy();
253         break;
254     case "ArrowLeft":
255         this.previousFrame();
256         break;
257     case "ArrowRight":
258         this.nextFrame();
259         break;
260     default:
261         break;
262 }
263 event.preventDefault();
264 };
265
266 onWindowResize() {
267     console.log("onWindowResize");

```



```

268     cornerstone.resize(this.element);
269 }
270
271 onImageRendered() {
272     console.log("onImageRendered ");
273     const viewport = cornerstone.getViewport(this.element
274         );
275     console.log(viewport);
276     this.setState({
277         viewport
278     });
279 }
280
281 onNewImage() {
282     console.log("onNewImage");
283     const enabledElement = cornerstone.getEnabledElement(
284         this.element);
285     this.setState({
286         imageId: enabledElement.image.imageId
287     });
288 }
289
290 async loadData(element) {
291     let studies_url = PACS_url + "/studies/" + studiesId;
292     let series = [];
293     let instances = [[]];
294     await axios.get(studies_url)
295         .then(response => {
296             series = response.data.Series;
297         })
298         .catch(err => console.log("error: " + err));
299
300     for (let index = 0; index < series.length; index++) {
301         let series_id = series[index];
302         let series_url = PACS_url + "/series/" +
303             series_id + "/instances";
304         instances[index] = [];
305         await axios.get(series_url)
306             .then(response => {

```

```

304         response.data.forEach(instance => {
305             instances[index][instance.
306                 IndexInSeries - 1] = instance.ID;
307         });
308     });
309     .catch(err => console.log("error: " + err));
310 }
311 this.setState({
312     series: series,
313     instances: instances
314 });
315 this.setImage(instances[0][0], element);
316 }
317
318 setImage(imageID, element) {
319     let url = PACS_url + "/instances/" + imageID + "/file
320         ";
321     url = "wadouri:" + url; // prefix the url with
322         wadouri: so cornerstone can find the image loader
323     cornerstone.loadImage(url).then(image => {
324         cornerstone.displayImage(element, image);
325     });
326 }
327
328 resetImage(imageID, element) {
329     let url = PACS_url + "/instances/" + imageID + "/file
330         ";
331     url = "wadouri:" + url; // prefix the url with
332         wadouri: so cornerstone can find the image loader
333     cornerstone.loadImage(url).then(image => {
334         cornerstone.displayImage(element, image);
335         cornerstone.reset(element);
336     });
337 }
338
339 componentDidMount() {
340     const element = this.element;
341     const gestureHandler = new GestureHandler();

```

```

337     gestureHandler.onGesture("open_hand_up", () => this.
        pan("up"));
338     gestureHandler.onGesture("open_hand_down", () => this
        .pan("down"));
339     gestureHandler.onGesture("open_hand_left", () => this
        .pan("left"));
340     gestureHandler.onGesture("open_hand_right", () =>
        this.pan("right"));
341     gestureHandler.onGesture("pinch_out", () => this.zoom(
        "in"));
342     gestureHandler.onGesture("pinch_in", () => this.zoom(
        "out"));
343     gestureHandler.onGesture("turn_clockwise", () => this
        .rotate("cw"));
344     gestureHandler.onGesture("turn_counter_clockwise", ()
        => this.rotate("ccw"));
345     gestureHandler.onGesture("swipe_up", () => this.
        nextFrame());
346     gestureHandler.onGesture("swipe_down", () => this.
        previousFrame());
347     gestureHandler.onGesture("swipe_left", () => this.
        nextStudy());
348     gestureHandler.onGesture("swipe_right", () => this.
        previousStudy());
349     gestureHandler.onGesture("C_swipe_down", () => this.
        contrast("dec"));
350     gestureHandler.onGesture("C_swipe_up", () => this.
        contrast("inc"));
351
352     // Enable the DOM Element for use with Cornerstone
353     cornerstone.enable(element);
354
355     this.loadData(element).then(r => console.log("data
        loaded"));
356
357     element.addEventListener("cornerstoneimagerendered",
        this.onImageRendered);
358     element.addEventListener("cornerstonenewimage", this.
        onNewImage);

```

```

359         window.addEventListener("resize", this.onWindowResize
360             );
361         window.addEventListener("keyup", this.onKeyPress);
362     }
363     componentWillUnmount() {
364         const element = this.element;
365         element.removeEventListener(
366             "cornerstoneimagerendered",
367             this.onImageRendered
368         );
369
370         element.removeEventListener("cornerstonenewimage",
371             this.onNewImage);
372
373         window.removeEventListener("resize", this.
374             onWindowResize);
375         window.removeEventListener("keyup", this.onKeyPress);
376
377         cornerstone.disable(element);
378     }
379     componentDidUpdate(prevProps, prevState) {
380     }
381 }
382 export default CornerstoneElement

```

APPENDIX

B

COMPLETE GESTURE SET

Gesture	Form
Swipe left	O
Swipe right	O
Swipe up	O
Swipe down	O
Turn invisible button clockwise	DP
Turn invisible button anti-clockwise	DP
Pinch out w/ index and thumb	DP
Pinch in w/ index and thumb	DP
Left hand C shape	SP + O
Right hand swipe up	
Left hand C shape	SP + O
Right hand swipe down	
Open hand in up direction	SPM
Open hand in down direction	SPM
Open hand in left direction	SPM
Open hand in right direction	SPM
Tap with index	DP
Thumb up	SP
Thumb down	SP

Table B.1: Complete gesture set

APPENDIX

C

GESTURE RECOGNITION RESULTS

Made with a Intel Core i7-7500U CPU @ 2.70GHz 2.90 - 12GB RAM

Gesture reconizer	Recognition accuracy	Time (ms)
ThreeCent	57,57	0,67
P3DollarPlus	45,79	0,10
Q3DollarRecognizer	40,07	0,84
Dollar3D	39,79	0,31

Table C.1: Gesture recognizer results - HandGestureDataset_SHREC2017_csv datasets - 7 training templates

Template number	Recognition accuracy	Time (ms)
2	98,06	0,04
3	98,88	0,03
4	99,00	0,03

Table C.2: Gesture recognizer results - PDollarPlusRecognizer - Smartphone dataset

APPENDIX

D

GESTURE REPRESENTATIONS

Go to previous study

Swipe right



Figure D.1: Swipe Right

Go forward

Swipe up



Figure D.2: Swipe Up

Go backward

Swipe down



Figure D.3: Swipe Down

90° rotation clockwise

Turn invisible button clockwise



Figure D.4: Clockwise Rotation

90° rotation anti clockwise

Turn invisible button anti clockwise



Figure D.5: Anti Clockwise Rotation

Zoom in

Pinch out with index and thumb



Figure D.6: Zoom In

Zoom out

Pinch in with index and thumb



Figure D.7: Zoom Out

Increase contrast

Left hand c shape
Right hand swipe up



Figure D.8: Increase Image Contrast

Decrease contrast

Left hand c shape
Right hand swipe down



Figure D.9: Decrease Image Contrast

Pan up

Open hand in up direction



Figure D.10: Pan Up

Pan down

Open hand in down direction



Figure D.11: Pan Down

Pan left

Open hand in left direction



Figure D.12: Pan Left

Pan right

Open hand in right direction



Figure D.13: Pan Right

APPENDIX

E

INTERACTION WITH EXPERTS OF THE FIELD

E.0.1 Medical Entrepreneurship Webinar by UStart

Représentant UStart : Pourriez-vous vous présenter brièvement, ainsi que votre parcours ?

Jean-Benoît Henry : Je suis ingénieur civil diplômé en informatique à Louvain-la-Neuve. Je suis passionné par l'esprit d'entreprise et lorsque j'étais étudiant, nous avons lancé une plateforme de covoiturage qui m'a appris les premiers pas de l'entrepreneuriat. Après nos études, nous avons continué cette plateforme de covoiturage et nous avons réalisé que financièrement, nous ne nous en sortirions peut-être pas aussi bien que nous le voudrions. J'ai passé un an en tant que consultant en stratégie. Pour retomber un an plus tard dans l'entrepreneuriat médical. Un monde qui n'était pas prédestiné pour moi mais qui montre certainement tout son potentiel pendant cette crise du Covid-19.

Louis-Philippe Broze : Je suis co-fondateur de la société Spentys. Que fait-on chez Spentys ? Nous personnalisons des masques d'immobilisation orthopédiques. Normalement, il s'agit d'attelles qui sont imprimées en 3D sur la base d'un scan 3D du membre et d'une modélisation 3D réalisée par le corps médical. L'attelle a l'avantage d'être légère, aérée, imperméable, faite sur mesure, recyclable et donc beaucoup plus confortable pour le patient.

Représentant UStart : Comment vous est venue l'idée de créer cette start-up et comment avez-vous décidé de lancer ce projet ?

Louis-Philippe Broze : L'idée m'est venue par l'intermédiaire de mon co-fondateur avec Florian. Nous étions passionnés et, nous le sommes toujours par la technologie 3D et nous avons réalisé que les plâtres et le marché des attelles. C'est un marché qui n'avait pas beaucoup évolué, qui avait plutôt stagné au cours des dernières décennies, et qu'il y avait aujourd'hui des technologies qui permettaient d'offrir une alternative avec beaucoup plus de confort pour le patient. C'est de là qu'est venue cette idée, au départ nous étions trois, donc les choses ont évolué.

Jean-Benoît Henry : Chez Toodoc on est un réseau collaboratif de disponibilité de praticiens. C'est à dire qu'on regroupe les agendas de nombreux praticiens en vue de ressortir les trous de dernière minute qui peuvent ensuite être pris par les patients en urgence. Il faut savoir qu'il y a énormément de d'annulation de dernière minute de la part des patients au sein de nombreuses spécialités et aussi qu'en tant que jeune praticien. Il est parfois difficile lorsqu'on sort des études de se faire une première liste de patient. On a donc évidemment des plages horaires libres également donc nous l'idée c'est de mettre à disposition pour un patient qui a une rage de dents, qui a un lumbago soudain, tous les problèmes qui peuvent survenir inopinément. Alors comment est-ce que l'idée s'est lancée en fait l'idée s'est lancée parce que le problème a été vécu par mon cousin qui est dentiste depuis un certain nombre d'années et c'est lui qui s'est rendu compte que les désistements lui faisait perdre un temps précieux puisqu'il devait pousser ses patients à deux trois semaines voire plusieurs mois parfois en fonction de ses disponibilités et du rush de la période alors que finalement au jour le jour ils se trouvaient qu'il avait parfois des trous qu'il fallait alors gérer en rappelant ses patients sur la liste d'attentes. Il a lui-même lancé un MVP en payant un développeur pour le faire et c'est seulement après que u'il ait pu prouver un certain intérêt. Il m'a convaincu de lâché ma carrière de consultant qui aurait pu être toute tracée pour me lancer avec lui. Donc à partir de ce moment-là on a essayé de d'étoffer les possibilités que pourraient offrir notre plateforme et maintenant qu'on pense avoir trouvé la formule. L'idée c'est vraiment de croître donc on est plutôt dans une phase de croissance.

Représentant UStart : À quel stade se situe Toodoc et Spentys aujourd'hui ?

Jean-Benoît Henry : On était deux cofondateurs au début et maintenant on est une équipe de 4 on espère qu'un cinquième nous rejoindra d'ici peu en développement. On a trouvé une formule au niveau de nos utilisateurs, on a trouvé une formule au niveau de notre business model qui est encore à affiner mais qui est présent et qui fait des rentrées. Donc on appelle cette phase plus la scalability. C'est à dire qu'on a on a une formule qu'on voudrait répéter et accélérer pour réellement le plus vite possible atteindre les différentes

régions géographiques et les différentes spécialités médicales qui ont un intérêt pour nous. Donc vraiment cette phase où on ne figole plus le produit et le projet mais où on veut accélérer la croissance de l'entreprise en termes d'équipe et de recrutement.

Louis-Philippe Broze : Concernant Spentys, on est une entreprise qui est je crois un peu plus un âge si je peux dire ça. La SPRL a été créée en septembre 2017. Aujourd'hui on est une douzaine de personnes. On a un siège social ici à Bruxelles et on a un siège d'exploitation aussi à Lausanne où là on a deux employés. On est actif dans plus de 5 pays donc principalement dans l'Union Européenne et à côté de ça on vient de clôturer une levée de fonds ici en mars de 1,7 million d'euro. Ce qui va nous permettre de faire en sorte de continuer notre développement ici en Europe et en dehors du marché européen.

Représentant UStart : Est-ce que vous pourriez nous donner deux, trois chiffres clés sur vos entreprises actuellement ?

Louis-Philippe Broze : Il y a un chiffre qui me tient particulièrement à cœur, c'est le nombre de patients qu'on a aidé à soigner. Aujourd'hui on est à plus de 1800 patients donc ça c'est vraiment un chiffre que j'aime bien partager surtout avec le monde médical. Car cela veut dire que Spentys a un sens, a une plus-value au niveau médical pour ces patients. Un deuxième chiffre c'est qu'on est une douzaine de personnes chez Spentys. Je n'aurais jamais imaginé ça il y a deux, trois ans quand j'ai lancé Spentys avec Florian. La dernière levée de fonds qu'on vient de faire de 1,7 million d'euros c'est quand même assez impressionnant. C'est aussi quelque chose que je n'aurais jamais imaginé et cela montre la confiance du marché pour amener Spentys à l'étape suivante qui est vraiment la globalisation de la solution.

Jean-Benoît Henry : Deux chiffres clés d'un côté et là je rejoins tout à fait Louis-Philippe c'est quelque chose qu'on partage beaucoup les jeunes entrepreneurs c'est l'impact social qu'on peut avoir. Notre métrique principale c'est le nombre d'urgence qu'on n'a pu soigner partiellement. On est à 15 mille la dernière année donc ça montre bien qu'en Belgique il y a également beaucoup de gens qui cherchent des solutions de dernière minute et qui n'en trouvent pas autrement que via un rassemblement de médecins. La deuxième métrique qu'on regarde également et qui rentre dans le fait qu'on se veut être une communauté un réseau collaboratif de praticiens. On est maintenant à 4200 praticiens.

Représentant UStart : Le monde médical est un marché spécifique et quelles sont exactement ces spécificités, par exemple les barrières à l'entrée, les opportunités et les menaces ?

Louis-Philippe Broze : Le premier défi qu'on a eu ici en lançant Spentys. Ce sont tous les aspects réglementaires donc on va fournir un dispositif médical ça a beau être une attelle ou un plâtre donc quelque chose qui est à l'extérieur du corps. Il y a pas mal de

réglementation à respecter et on est dans un cadre législatif l'union européenne qui est assez complexe donc chaque pays a un peu ça petite popote. Même s'ils sont en train de s'uniformiser. A côté de ça il y a tous les aspects de remboursement et donc pour obtenir les remboursements parce qu'on a la chance ici en europe continentale d'être dans des systèmes de soins de santé qui sont quand même pas mal remboursés. A côté de ça c'est aussi convaincre l'environnement hospitalier l'environnement médical de la plus-value et de l'innovations. On a beau dire que la médecine innove beaucoup c'est quand même un secteur qui est très traditionaliste et qui a beaucoup de mal à essayer de changer ses habitudes, changer ses rituels. Donc ça c'est aussi beaucoup de travail chaque jour pour prendre son bâton de pèlerin et faire en sorte de convaincre l'ensemble des stakeholders du marché.

Représentant UStart : Le fait d'aller en Suisse ça a été un problème ou pas pour vous ?

Louis-Philippe Broze : Le fait d'aller en Suisse c'était un peu différent effectivement mais bon les suisses suivent assez les réglementations européennes mais ce qui était intéressant la suisse était surtout le dernier aspect que j'ai soulevé dans le point précédent. C'est le fait que là-bas les docteurs sont beaucoup plus innovation-friendly comme on dit et donc ils sont beaucoup plus sensibles à l'innovation et donc on a beaucoup moins de travail à faire pour les convaincre d'utiliser notre solution par rapport à la Belgique.

Jean-Benoît Henry : Il y en a une qui est fort proche de celle de Louis-Philippe. Outre les réglementations, il mentionnait le côté très traditionnel de la médecine en Belgique et que c'était une raison notamment pour laquelle il a été voir du côté Suisse. Je pense que même au niveau purement digital c'est très vrai. On a un système médical en Belgique que j'appellerais presque corporatiste sachant que chaque spécialité médicale dispose de sa propre association de son propre ordre. Il y a énormément de pouvoir politique sachant que voilà l'INAMI et la SPF santé sont gérées par le fédéral. Mais si vous allez voir les maisons de repos ou bien certains financements des hôpitaux, c'est au niveau régional. Il y a une complexité administrative mais il y a aussi un traditionalisme sur tous ces aspects-là donc des institutions publiques et médicales qui freinent beaucoup d'innovations malheureusement en Belgique. C'est vraiment un constat qu'on a dû tirer et ça m'amène à un deuxième point qui n'est pas lié aux institutions publiques et médicales mais plus au personnel médical en tant que tel. Ici on parle vraiment pour nous uniquement des médecins ou même de tout praticien indépendant donc hors hôpital on a eu un niveau de digitalisation qui est encore très bas et dont l'explication se situe assez facilement dans la pyramide des âges qui est publié quasiment annuellement par le SPF santé. Malheureusement il y a encore une pyramide qui est inversée, on a 55% des médecins généralistes en activité en Belgique aujourd'hui qui ont plus de 55 ans. Du coup, au niveau

de la digitalisation évidemment fort lié à cette pyramide des âges et pour des solutions digitales comme la nôtre évidemment c'est un frein conséquent.

Représentant UStart : Avez-vous d'autres produits que l'attelle pour le bras ?

Louis-Philippe Broze : Traditionnellement on propose une solution qui va permettre la customisation de masse pour l'ensemble des parties du corps des immobilisations orthopédiques. Ça peut être les membres inférieurs, ça peut être des minerves, ça peut être des casques. On s'attaque aux pathologies plus chroniques et aussi des pathologies beaucoup plus traumatiques donc quand on se casse un membre. Mais à terme la vision de Spentys ce n'est pas se limiter dans la customisation de masse seulement dans l'orthopédie ou seulement dans les immobilisations orthopédiques mais c'est aussi essayer de se diversifier avec des implants chirurgicaux vers des prothèses des semelles orthopédiques. Donc c'est vraiment faire en sorte d'être un catalyseur de la customisation de masse dans l'orthopédie en général. Ça c'est un peu la mission de Spentys, c'est amené cette customisation de masse dans le monde de l'orthopédie parce que chaque patient est différent et donc chaque patient mérite une immobilisation orthopédique sur mesure. Mais aussi un dispositif médical qui soit unique et donc qui prenne en compte son anatomie mais aussi son environnement.

Jean-Benoît Henry : Des services supplémentaires seront ajoutés et c'est le propre du digital, car une fois qu'il est construit, il reste et vous pouvez imaginer quelque chose autour.

Représentant UStart : Avez-vous beaucoup de concurrents ?

Louis-Philippe Broze : On a des concurrents et tant mieux car cela prouve qu'il y a un marché, ça prouve qu'il y a de l'intérêt de la part du marché. On a des concurrents ici en Europe, aux États-Unis, en Asie. L'un des avantages de Spentys, c'est le fait qu'on va couvrir vraiment l'ensemble de la chaîne de valeur, l'acquisition d'images 3D, un software de modélisation 3D et aussi des techniques d'impressions 3D.

Jean-Benoît Henry : Bien sûr, je prends une approche théorique mais on a les substituts c'est à dire un bête coup de téléphone à vos praticiens ou bien une recherche en ligne sur Google Maps. Puis, on imagine souvent que nos concurrents directs sont les agendas médicaux il en existe d'autres qui permettent de chercher des praticiens typiquement Dranytime ou Doctena je ne sais pas si ces noms vous disent quelque chose mais si vous avez déjà dû chercher un praticien en ligne en urgence et souvent ces solutions là qu'on trouve. En fait, ses concurrents n'en sont pas, ce sont des partenaires puisque Toodoc les regroupe c'est à dire que les rendez-vous qui sont mis en ligne publiquement sur ces plateformes et ces agendas qui sont en fait des solutions cachettes des praticiens et ben on les absorbe grâce à une API pour les rendre disponibles aux patients. On est en fait un service complémentaire qui se différencie au niveau de la compétition c'est notre

focus sur l'urgence.

Représentant UStart : Est-ce que votre produit touche seulement le marché belge et peut-être si oui pour l'instant, qu'est-ce que tu comptes faire dans le futur ?

Jean-Benoît Henry : Oui, alors notre plateforme actuellement n'est disponible qu'en Belgique. Je dirai même qu'elle est beaucoup plus centrée sur Bruxelles et la Wallonie que sur la Flandre puisque les groupements de pratiques médicales sont groupés au niveau ordre ou associations aussi par région linguistique donc on les touche plus facilement d'un côté ou de l'autre. Évidemment en fonction de la concurrence toujours donc c'est à dire des plateformes existantes dans les pays voisins au niveau de l'urgence médicale. On a déjà en tête les pays limitrophes qui sont les plus les plus abordables. Je pense notamment au Luxembourg, les Pays-Bas, et potentiellement l'Allemagne sachant que la France typiquement est déjà saturée par un gros acteur qui englobe toutes les réservations médicales en France.

Représentant UStart : Louis-Philippe, tu as dit que tu exportais déjà un peu partout, peux-tu nous donner plus de détails à ce sujet et nous dire aussi quels sont tes projets pour l'avenir ?

Louis-Philippe Broze : Donc on a vraiment un focus ici sur l'Europe donc comme je disais on a déjà ouvert une succursale en suisse à Lausanne, on est actif au Luxembourg, aux Pays-Bas, en Allemagne et en France et aussi en Israël. Le but c'est d'aller assez rapidement aux États-Unis pour pouvoir prouver la traction du marché et aussi pour pouvoir voir si notre modèle peut s'adapter à un système de remboursement qui est totalement différents. On a vraiment une stratégie assez agressive qu'on va qualifier de first-mover. On veut rapidement aller locker un maximum d'hôpitaux, de centres médicaux pour voir rapidement prendre des parts de marché. On a la conviction qu'en fait dans le milieu médical surtout quand on signe un contrat avec un hôpital avec une institution hospitalière. Les switching cost donc les coûts de changement pour ces institutions de changer de fournisseurs sont assez élevés et donc en arrivant en premier on a quelques facilités pour faire en sorte de garantir une certaine pérennité avec le client.

Représentant UStart : Comment vous vous êtes fait connaître dans le monde médical ?

Jean-Benoît Henry : Moi je peux commencer peut-être. On s'est basé sur le réseau de mon cousin d'abord qui est lui-même dentiste comme je disais depuis plusieurs années. Après, c'est énormément de travail parce que c'est un milieu médical qui est comme on le disait traditionnel donc très organisés en ordre, en association donc il faut être introduits, il faut convaincre. L'avantage par contre c'est qu'une fois que tu les as convaincu et bien tu y restes. Il y a plusieurs stratégies soit via les institutions publiques, soit des institutions

plus scientifiques soit via les patients directement.

Louis-Philippe Broze : C'est très intéressant le point que tu viens de soulever car nous avec le push patient on a toujours un peu peur. En Europe, en tout cas c'est l'idée qu'on a mais on a toujours l'impression que le patient est la propriété du médecin. C'est pour ça qu'on a un peu peur qu'un patient demande à un médecin notre solution car ils pourraient se dire « pour qui ils se prennent cette start-up à essayer de m'enseigner mon métier. » Ce qu'on fait nous en termes de stratégie, on va se focaliser sur des key opinion leader. Ces gens-là, on va faire des études cliniques avec eux sur cette base là on va créer une certaine légitimité scientifique et ça va nous permettre d'être avec eux aux congrès médicaux et de partager avec eux et avec leurs collègues et donc de faciliter le processus de commercialisation.

Représentant UStart : Avez-vous des outils juridiques qui vous aide à vous protéger ?

Louis-Philippe Broze : Ici chez Spentys, on n'a pas spécifiquement de brevet. On a des dépôts de modèles, ces dépôts de modèles permettent de pas être copié vulgairement. On va plutôt pratiquer le « secret professionnel », on a notre plateforme qu'on a développé avec une certaine logique sur une certaine plateforme où on est les seuls à avoir ça et cette logique de développement. On a préféré pas la breveter car à partir du moment où tu brevètes ça va tomber dans le domaine public et donc c'est possible que quelqu'un puisse copier ça même si le brevet ne passe pas. On se protège en signant des contrats avec nos sous-traitants, nos partenaires.

Jean-Benoît Henry : Nous c'est propre au digital, on parle énormément du GDPR. Quand on parle de digital médical, on est encore à un seuil au-dessus puisque c'est du secret médical qui vient s'ajouter au GDPR. Il y a donc énormément d'attention qui doit être portée sur les données qui sont enregistrées, les communications, qui a accès à quoi et donc on se fait aider par des avocats qui s'y connaissent car on n'a pas les compétences en interne.

Représentant UStart : On a pu voir que vos deux start-ups ont réagi de manière assez intéressante à la crise actuelle. Quelle a été votre première réaction par rapport au lock down ?

Jean-Benoît Henry : On a d'abord eu une réaction opérationnelle. Déjà même avant l'annonce du lock down on avait l'avantage d'être une équipe digitale donc n'avait déjà proposé à tout le monde de travailler de la maison. Puis, ces réactions opérationnelles sont devenues des opérations forcées. S'en est rapidement suivi des décisions plus stratégiques. C'est à dire finalement cette crise c'est une opportunité en même temps qu'une menace. Pour Toodoc, il y avait une menace très claire c'est à dire que tous les soins ambulatoires

ont été arrêtés. Nous notre plateforme a dû être coupée car on pouvait plus prendre rendez-vous chez les praticiens. Il y avait une opportunité car qui dit réorganisation complète des soins ambulatoires dit opportunité d'être celui qui les facilite aussi bien du côté des patients que des praticiens.

Louis-Philippe Broze : Initialement avec Florian, on ne s'est pas vraiment rendu compte de l'ampleur de la crise. On a suivi ce qui avait été recommandé par l'état fédéral et par la cellule de crise. On a envoyé la majorité des employés chez eux et seulement garder quelques employés qui étaient nécessaires pour la production. Puis, on a commencé recevoir pas mal de demandes d'hôpitaux pour développer des produits et on a donc réalloué l'ensemble de nos ressources car on avait presque plus de commandes. On a réalloué notre production, modélisation et forces à la production de différents aspects. Des consommables pour des appareils d'assistance respiratoire, des masques visières écran de production, des ouvres portes.

Représentant UStart : Faites-vous appel à une aide quelconque ?

Jean-Benoît Henry : On a contracté un prêt qu'on va devoir rembourser. Ces prêts n'ont malheureusement pas été aussi facilement octroyé qu'en temps normal. C'est assez normal puisqu'on est une entreprise digitale et que par conséquent on est moins touché par la crise.

Louis-Philippe Broze : Nous on a eu beaucoup de chance car on a su clôturer la levée de fonds le 15 mars juste avant le début du confinement. On a su faire signer tout par procuration, on a eu beaucoup d'argent qui est arrivé d'un coup donc le problème des trésoreries on ne l'a pas. Après, on a eu une chute d'activité, et on a dû par conséquent mettre des gens aux chômage techniques.

Représentant UStart : Comment pouvons-nous motiver ces employés alors que nous sommes au milieu d'une période de confinement ?

Jean-Benoît Henry : C'est une excellente question ! Parce que c'est beaucoup plus difficile qu'on ne le pense. Tout le monde est touché par ce confinement, surtout au niveau psychologique dans sa motivation à travailler. Sans interaction, que ce soit avec ton équipe, avec tes clients ou avec tes utilisateurs. Il faut trouver cette source d'énergie parfois ailleurs et par vidéo on a beau se voir ce n'est pas la même chose non plus. Nous on a adopté des check-in plus fréquents en fonction du travail de chacun. On a essayé de mettre des moments plus fun, dans le sens où auparavant on avait des baby-foot et des bêtises comme ça. Maintenant on va jouer à Scribble par exemple.

Louis-Philippe Broze : Chez Spentys on a une composante production donc il faut faire tourner les machines. Surtout qu'il y a une demande de la part des hôpitaux pour ces

visières de protection et pour ces consommables d'appareils d'assurances respiratoires. En effet, on a reçu pas mal de commandes de pas mal d'hôpitaux dans pas mal de pays (en France et aux Pays-Bas). Il y a donc une présence physique qui est nécessaire. Puis, il y a tous le département IT qui travaille de chez lui, donc là effectivement notre responsable IT, notre responsable recherche et développement s'organise de façon quotidienne des calls pour faire en sorte de tenir les gens motivés.

E.0.2 Surgical Safety and Social Distancing Webinar by Caresyntax

On this [hyperlink](#) is the retransmission of the webinar. Please note that the main speaker had a strong accent and difficulties to speak English, therefore some sentences do not always have a clear meaning but the idea can be understood. Some slides that are relevant to the research of this master thesis have been added.

Enrico Commisso : I'm an international training education manager a Caresyntax today as you know we will talk about surgical safety and social distancing in particular we'll give you tips for healthcare professional working actually in Covid-19 environment as you can see I'd like also to introduce to you today's main presenter dr. Lorena Pingarron. She's working as a head of oral and maxillofacial surgery at the University Hospital Rey Juan Carlos in Madrid. So before I hand over to Lorena I'd like to give you a quick overview about the world situation regarding corona virus and some important information about Caresyntax. The Covid-19 pandemic, as you know, threatens to overwhelm a care system the number across the world are frightening and this has been particularly challenging for frontline givers as the risk of contact contamination is high and avoiding contact is the primary infection preventive measure. As you know the situation is fluid and dynamically changes hour by hour. New data regarding epidemiology treatment are released daily. So moreover we can see that we have a broad geographic distribution about Covid-19. And as you can see unfortunately from what I am showing , we have more than 2 million cases . The data were updated in the latest 24 hours and more than 170,000 deaths. So when Dr. Lorena Pingarron will talk about explaining the possibility of minimizing the risk of contact contamination in a medical device to be consulted by voice inside the operating room. All the care community paid attention. In the next upcoming slides Doctor Pingarron will talk about how her team used the IoT in voice activation technologies from Caresyntax at this critical time. With Caresyntax solutions, her team delivered effective infection protection through seamless gesture and voice control of medical device in intensive care units and the operating room. And successfully lowered the risk of contact contamination while improving the quality of care and patient safety. Let me say something about our company so about Caresyntax with a quick introduction. Caresyntax is working to make mission-critical care settings such as surgery interventional radiology and obstetrics

smarter and safer. The company proprietary solution leverage IoT analytics and artificial intelligence technologies to automate clinical and operational decision support for surgical teams in support all outcome contributors in the delivery and management of risk bearing contracts. By integrating data from medical device, electronical health-records and other sources inside hardwares. And unified in a Data Platform, Caresyntax helps caregivers better identify manage risk increased work efficiency, reduce surgical variability improve operational or clinical outcomes at the endpoint of care. Caresyntax technology as you can see in the slide, are used in **more than 7,000 operating rooms worldwide** and support surgical teams in **over 10 million procedure per year**. One of our flagship product is our IOT connectivity platform six prime. Six prime is the control center for operating rooms features image and video management documentation telemedicine with embedded the software based the video conference solution and IT interface on a single user platform. By capturing the full spectrum of surgical data from inside the operating room, our data driven digression provides the total visibility to achieve increase the workflow efficiency, patient safety and surgical performance. One of our main key, all marks are that we have a dashboard app based usability, interoperability, flexibility intelligence and modularity. And that's why today, one of the models that we want to share with you and also the experience of the Doctor Lorena Pingarron is the module on the platform name the Six Reach which is the topic of our today webinar. Just a brief introduction, Six reach provides the surgical team with touchless control over connected device using the combination of voice and gesture commands. Now, I like to hand over to Lorena Pingarron, she will share with us the experience before Covid-19 and during Covid-19 environment in her hospital.

Dr. Lorena Pingarron : So, good afternoon dear colleagues, in this webinar I would like to show you my experience as frequent user of touchless technology and much more now in these biological pandemic scenario. To give a brief introduction, I want to show you where I work. This is the view of Rey Juan Carlos University Hospital, one of the four public hospital of [Not understood name], our health care system in Madrid. This was the situation in our Hospital just two months ago, the 6th of March. We were working in a team concept much more closer physically and relaxed regarding the contamination in terms of biology transmission. But things changed, all over the world, faster that everyone could imagine and we had to adapt all the hospital work to the management of the disease. The disease in Madrid increased dramatically but also in the ICU (Intensive Care Unit), and with that the deep rate. So from the 6th of March, we work in an effort to anticipate the situation before the peak, during the peak and we are thinking about the re-entry phase. So right now, comparing with the prediction we perform with big data and the real situation, we can see that it was in two different phases. So how are we working ? What was our approach ? We have to work following and strictly the instructions

from the Emergency Committee established at the hospital. The corporate decisions in our Hospital where to centralize the management of all available personal, clinical and non-clinical for relocation of duties. Changing working partner patterns to sterilize the silk with around Covid and non Covid to work very deeply in telemedicine and the pace change folder application changing the organizational structure with single critical care unit that were composed with the intensive care doctors clinical and surgical nurses, then are sociology department. We created an intermediate respiratory care unit that was really very important for all those patients who could not be all in the intensive care units. The oncologic patients are immunosuppressive patients so they can not stay all around join with the Covid patients. So we canceled all elective surgery and we are right now starting with all that kind of surgery, we focus on the emergency surgeries. The telemedicine was really an important tool for patient follow-up, not only for the Covid period and we are working right now in that to establish this kind of medicine for the future and in fact we can see how with this tool we got to solve till the 80% of the review in the outpatient clinic. **TedCas medical system made a partnership with Caresyntax** it makes easier the telemedicine with this video platform for a close follow up with our patient and also for the patient in the ICU communication with their families. We maintained all the infection protection measure and here is how Caresyntax has a great tool because we are able to perform a touchless control of multiple medical devices simultaneously.

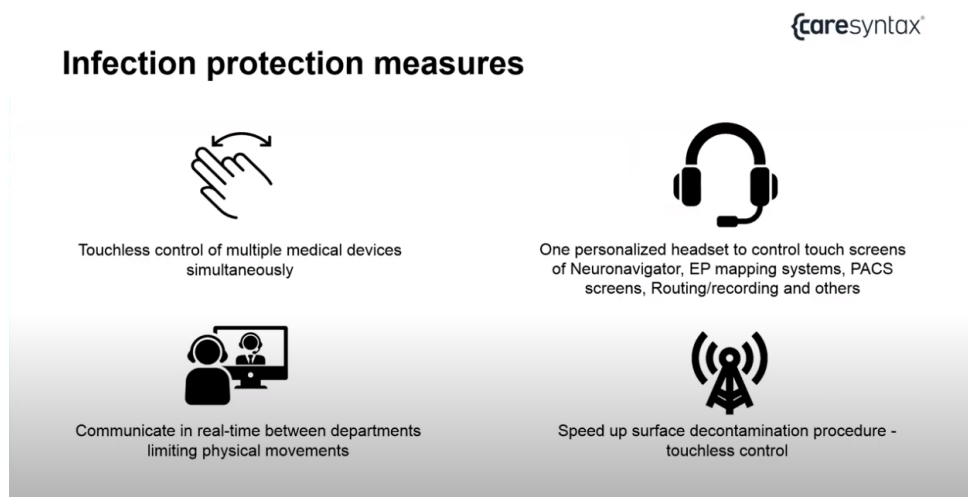


Figure E.1: Slide Webinar Caresyntax

One personalized headset to control touch screens and Neuronavigator. There with all the mapping system, back screen, routine recording and others, to communicate in real-time not only with the patient and the professional but also very important between departments. Departments telecommunication limit physical movements and speed up soon face the contamination procedures with a touchless control. I mean this copied period this is really very important because in the operating room between one patient till the

other one to perform an adequate cleaning of all the surfaces, we have to wait 25 minutes between the entrance of the patient till the prior one exit so the speed up surface the contamination procedure is very important and if we have control all the devices with touchless so all the contamination is much more efficiency.

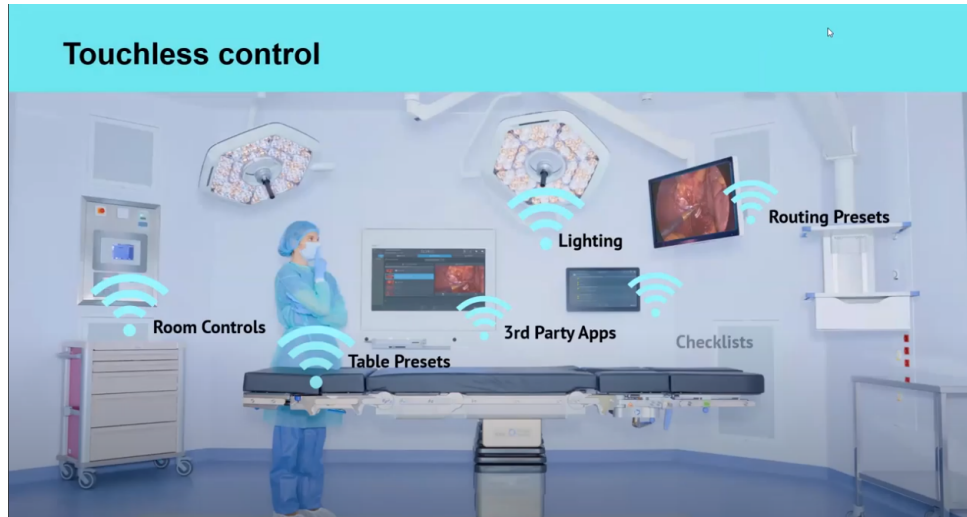


Figure E.2: Slide Webinar Caresyntax

So this is the view of one of our intelligent operating rooms so you can add this is our operating room but all of you have different ones. So here you have how you can adapt all the Caresyntax technology with touchless control: the room controls, tablets, the third power application to control the light, routine procedures, perform the checklist in the three phases. Voice command allows you to adapt all in your particular way. So let's see the technical specification of Caresyntax. The touchless control works in the next way, the Caresyntax has partnered with TedCas which is based in Spain, has allowed us to integrate the receiving sensor. Caresyntax is a combination of an additional hardware component within the console as well as integrate configuration and controlling software. So for upgrades to existing consoles the one that you have at hospital you don't have to buy additional console as it works with the one you have. You just have to adapt the hardware component with the connection very easy with a simple USB so the mouse and the keyboard software emulation is configurable and they gesture on the voice commands are configured by myself during the installation and there is a great big library of gesture and it's available for selected sensor and the mapping is customized by end user. Underlying technology is not classified as a medical device so you don't need an extra approval, it complies with medical devices close one the vendor is neutral this is great because you can adapt the console and all the devices you have in your own hospital. And is compatible with all reputable sensor on the market and it's a standard package that includes one option for voice control and one option for gesture control depending of your preferences. The concept in the technology which we use in our hospital make us is a CCA as the

concept in technology that make us easier the dial in our leisure time, we want to track the route and register the training and to share this training with our colleagues. So at hospital we stayed in the same concept: we set the route followed for the patient with a simple medical bracelet, then since the patient entered in the hospital we can track all the route that he is following since the patient is just entering, then he is just in the change room, then he is in the preparation room, then he is entering in the operating room and exit missing the reanimation room. This is very important not only for communication between departments between the nurses with the surgeon or with the anaesthetist. But it is also very important for the family of the patient that with a simple screen that is in the waiting room, the family can follow the track that the patient where the patient is. So they can know exactly that it has to spend 20 minutes is not because it has already the operation has a star 20 minutes ago. No because maybe he is just entering in the OR.

At 16:55, a use of the machine with **voice** control is shown.

At 17:57, a use of the machine with **voice and gesture** control is shown.

Dr. Lorena Pingarron : You can see how you do not need to scrub or to ask the nurse to check the MRI images or to order that they interpret a biopsy, you can control the devices by yourself. And you can see on the screen that the configurations can be adapted in relation to the preferences of the user. An operating room is a complex environment and you can see how this system can be a real plus. You can see the console and with this latter we can control the microscope, the light, the zoom, you can take a picture. It reduces the stress, not only for the surgeon but also for the nurses. You can see that the scenarii with the voice and touchless control is completely different, you can ask much more orders, not just such in a mess, absolutely efficiency and being able to reduce the risk of contamination. This technology is not only efficient in the operating room, it is also very useful in the ICU (Intensive Care Unit). You can control the different screen that are in the room thanks to this device. The voice control command functions with our solution CX Reach that is available in multiple languages like English, Spanish, German, Dutch, French and Italian. The device is fully configurable and there is no voice training required. In my preference, I prefer the voice control because my arm is really thin so maybe the bracelet is not as comfortable for you, but you have the choice of the armband that is sterilized. It is also water resistant. You also have the choice of the intelligent webcam. But you can also choose the three of them.



Figure E.3: Slide Webinar Caresyntax

You can see that the device is a simple little box that has a USB entry that you connect in the device that you want to control like the microscope or in the tower of the laparoscopy or in the neuronavigator. It is very simple to connect and to adapt the voice and gestures commands depending on your preferences.



Figure E.4: Slide Webinar Caresyntax

This allows to improve the patient safety for sure and reduction in surgical site infections due to less movement within the OR. The surgical team can access and control the critical information on the screens without having to leave the sterile zone or to order to the nurse to check the screen for you. Simultaneously, you can control multiple connected devices, as you saw in the video how we are controlling the microscope with the neuronavigator. It allows to surgeons to maintain their focus on the surgery and on the patient with minimal distractions.

Benefits of Touchless Control in CX-PRIME

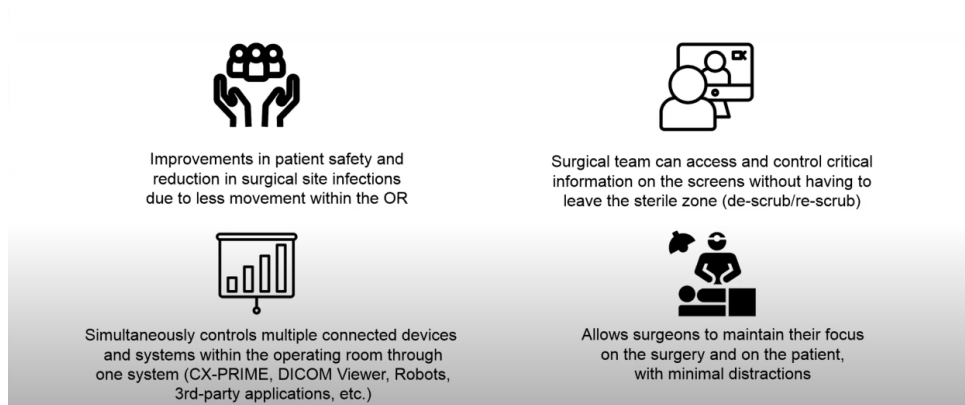


Figure E.5: Slide Webinar Caresyntax

The process to scrub out, to review data, and scrub back takes on average 8 minutes. This is cost beneficial as it saves time. And now in the Covid period, this is much more important because if you save time, this will be translate in even more cost reduction because right now, as I told you before, you have to wait 25 minutes between one surgery to the other one, so that everything can be cleaned. To sum up, we can say that Caresyntax with TedCas technology takes your clinic in a safer environment. The efficiency increases. And the voice control can be applied to many applications. Thank you for your attention, now you have the options for questions. We selected the most relevant questions of the Q&A.

Enrico Commisso: Did it help to reduce nurse capacity during procedures?

Dr Lorena Pingarron: Depending the day, it happens that you have 3 or 4 complicated procedures, it happens that you need extra nurses. One can be giving the instruments, the other doing a biopsy etc. Thanks to this you do not need one to manipulate the medical data. It relieves stress for the nurse.

Enrico Commisso: Does all the operating rooms and ICU have this specific system integrated?

Dr Lorena Pingarron: not understandable.

Enrico Commisso: Could we have an idea of the budget of the integration of such a solution? ... Well it really depends how many controls, consoles... This is an answer we can respond separately.

Enrico Commisso: In case of failure of the voice and recognition system, is it possible to use the mouse and the keyboard easily?

Dr Lorena Pingarron: Yes, the mouse and keyboards do not stop during the intervention.

E.0.3 Exchange with Gerardo Gonzalez - Microsoft Researcher on touchless surgery

Jean Wilberz : Does the researches you did with the Microsoft Research Cambridge team led to the creation of a company?

Gerardo Gonzalez : I am afraid no, the work I did was only for research purposes and the objective of the work was to understand who people (in this case surgical teams) interact with new technology. The research we did involved developing a bespoke system that addressed the exact requirements of a couple of surgical teams (vascular and neurosurgery teams), from how they interacted and worked amongst each other, the constrained space in which they worked next to the patient, the instruments they used during the surgery, etc. All the intellectual property from the touchless project belonged to Microsoft and any invention derived from it was property of Microsoft. From the point of view of Microsoft the project and its associated money budget finished after 2 years. No intention was given to continue the work.

Jean Wilberz : Do you think that touchless gestures interaction with medical data will appear in the coming years into operating rooms?

Gerardo Gonzalez : Possibly, but I wouldn't expect any major development in this area any time soon. A lot of people were interested at the time as it was something new and a lot of attention was given to gesture - from gaming, TV sets (with gesture control) to desktop control. I believe this attention has changed for the last few years and now much of the innovative work is focused on speech recognition (e.g. Amazon Alexa, Google, etc). Back then surgeons wanted a commercial product developed by Microsoft to use in hospitals, but Microsoft didn't follow this as describe in the point above (Microsoft wasn't that interested in medical imaging at the time, but this may change in the future).

Jean Wilberz : Do you know the names of companies that also operate in this field? In the scientific articles "Touchless in Interaction Surgery", there are a lot of references but only of researchers. Here are the names of companies we have found that are active in this sector: STS progesoftware, TedCas, aeroTAP

Gerardo Gonzalez : Yes, the scientific paper focused mainly on research teams as they were the ones creating innovative work for gesture. At the time there were not many companies doing gesture for medical data. The few companies I knew at the time was GestSure (one of the first ones to develop such a system), Virtopsy (check: <https://www.youtube.com/watch?v=b6CT-YDChmE>), and TedCas. I am not sure of more

recent companies.

Jean Wilberz : Has a team continued on the researches you did in the field of touchless interaction in surgery? The articles that were redacted by the Microsoft Research Cambridge team are in the period between 2011 and 2015. According to our researches, we haven't found any after. Except from 2018, researches seem to focus on the gesture recognition abilities of the HoloLens (rather than the Kinect). Could this be seen as a continuation of the researches you did back then? Or this could be used in parallel with the Kinect?

Gerardo Gonzalez : I have left the organisation I have worked on other projects since. I don't think the remaining people in the team have continued this research. As the research was aimed to understand the capabilities of gesture recognition, I would think this would have influenced other areas for gesture recognition in the operating room using other technology such as the HoloLens. From what I can see briefly in the journal paper from the news article, the research team carried out an independent research but not based on my previous work. It could be used in parallel with the Kinect system, in which the Kinect recognises the body of the surgeon and recognise coarse gestures while enhancing a fine-grained set of gestures (e.g. finger movements) using the HoloLens. I believe that the key thing for a new company would be to adapt new technology and methods to the current medical procedures rather than the other way around, so this can be accepted in the medical practice and be more successful.

E.0.4 Exchange with Jesus Miguel Perez - TedCas CEO

We have reached several actors on the market of touchless interaction in operating rooms to understand it better. Namely, the CEO of TedCas, our biggest competitor. We asked him a list of questions but he decided to answer those only, as the current period require many of the services his startup provides.

Jean Wilberz: Why did so many actors left the market of touchless surgery of medical data? I am thinking of GestSure, KiOP, MotionView, Opect etc.

Jesus Miguel Perez: In my opinion there are several possible factors:

- The approach of many of these companies is too narrow in the sense that they offer their own gesture/voice platform to control their own software. It makes it difficult to integrate with current OR equipment (which is what surgeons need to control)

- The healthcare sector needs a lot of money in the bank to survive, as you need to certify, create pilots, test, have the first payors, get the money (in healthcare sector it sometimes takes a lot of time and depending on the Country and cost of the product you

need to go through a public tender which is not easy...)

-Testing and creating the right product with the right UX/UI is not easy when you need to test and pilot inside the OR

Jean Wilberz: When the Kinect disappeared, did it had an impact on your business?

Jesus Miguel Perez: Not really. We originally created TedCube to be compatible both with any kind of medical equipment and any kind of sensor, so we only had to offer sensors similar to Kinect

Jean Wilberz: Do you have some indirect competitors? Which is to say, solutions that respond to the same need that you tackle.

Jesus Miguel Perez: Well, you could think of sterilizable mouse/keyboards but they use is much more limited than fully touchless control.

E.0.5 Exchange with Belgian Surgeons

Préambule

En pleine période de Covid-19, approcher des chirurgiens est extrêmement compliqué. Nous avons donc cherché le moyen le plus simple de pouvoir récolter des informations tout en leurs faisant perdre un minimum de temps. C'est pour cette raison que nous avons opté pour une étude qualitative via un questionnaire en ligne que nous leurs envoyons via e-mail et pour lequel ils pouvaient répondre quand ils le désiraient. Grâce à ce questionnaire en ligne nous avons pu récolter différentes informations qui seront partagées et analysées ci-dessous. Nous avons eu la chance dans cette période de crise de tout de même avoir 6 réponses de chirurgiens différents ce qui montrent tout de même leurs intérêts pour de nouveaux projets innovants.

Présentation Questionnaire

Introduction

« Afin de réaliser notre thèse de CPME (majeure en entrepreneuriat), nous avons décidé d'étudier la faisabilité de la création d'une entreprise dans le domaine de la médecine technologique. La mission de cette entreprise sera de faciliter l'interaction homme-machine dans les salles d'opération mais aussi d'y préserver sa stérilité. Comment allons-nous réaliser notre mission ? Nous voulons mettre en place une caméra et un logiciel dans les salles d'opération qui permettraient aux chirurgiens de contrôler les images médicales d'un simple geste pendant l'opération. »

1) Quel type d'opération menez-vous? (Chirurgie vasculaire, chirurgie digestive, etc.)

- 2) Avez-vous besoin de consulter des images médicales lors de vos opérations ?
- 3) Sur quel type de moniteur sont-elles retransmises ?
- 4) Quel logiciel utilise votre hôpital pour lire ces images médicales ? (Osirix, Phasya, etc.)
- 5) Quelles sont les contraintes auxquelles vous faites face en salle opératoire ?
- 6) Existe-t-il des produits similaires dans votre hôpital?
- 7) Remarques

Exploitation des Données

1) Concernant la première question, cinq de nos six répondants sont des chirurgiens spécialisés dans la chirurgie digestive. Un seul des répondants quant à lui est chirurgien cardiaque. Des questionnaires avaient été envoyés à de nombreux chirurgiens ayant des spécialités variées néanmoins on peut observer une nette majorité de chirurgiens digestifs ce qui nous amène à poser une première hypothèse : Les chirurgiens digestifs seraient peut-être les plus enclins à l'innovation.

2) Concernant la seconde question, tous les répondants ont répondu « oui ». En effet, il semblerait que la consultation d'images durant les opérations aussi bien digestives que cardiaques est nécessaire.

3) En ce qui concerne la troisième réponse, les répondants étaient unanimes pour dire que le moniteur utilisé dans les salles opératoires est un écran d'ordinateur.

4) Pour ce qu'il s'agit de la quatrième question, l'ensemble des chirurgiens semblent utiliser Carestream comme PACS. Ce qui peut s'expliquer par le fait que tous les répondants sont des chirurgiens des hôpitaux de l'UCL.

5) En ce qui concerne la cinquième question. L'un des répondants a mentionné l'écran de petite taille. Quatre autres ont relevé le fait qu'il dépendait d'un tiers pour avancer soit d'une infirmière soit d'un anesthésiste. Finalement, une dernière personne ne voit aucune contrainte.

6) Pour ce qu'il s'agit de la 6ème question, aucun chirurgien ne semble avoir une alternative dans son hôpital. Ce qui pourrait nous conforter dans l'idée qu'il n'existe pas ce type de service en Belgique. Néanmoins, à nouveau seuls des chirurgiens faisant partie d'hôpitaux de l'UCLouvain ont répondu.

7) Deux remarques ont été laissées: "Votre projet est intéressant", "projet d'entreprise innovant"

E.0.6 Interview with Matthieu Palate and Christophe Dumonceau

Harry Usuwiel : Tout d'abord, nous aimerions savoir si notre mémoire appartient à l'UCL ?

Matthieu Palate : Pour répondre à cette première question sur la propriété intellectuelle. En début de mémoire vous avez tous signés une cession de droits. Qui cède vos droits de propriétés intellectuelles. Donc, les propriétés sur les résultats de recherche dans le cadre de votre mémoire à l'université. Nous avons demandé à Jean de faire cette cession de droit afin de garantir une certaine homogénéité entre ce qu'il avait développé dans son code Gestus et ce que vous allez développer. Donc, si vous voulez créer une société sur base des résultats que vous obtenez de votre mémoire CPME ce sera de facto une société Spin-off puisqu'elle reposera sur des résultats issus de laboratoires de l'université.

Harry Usuwiel : quels sont les critères pour devenir une société spin-off ?

Matthieu Palate : Une spin-off ce n'est jamais qu'un terme qui désigne une start-up, une société qui issue d'un laboratoire universitaire ou en tous cas qui se base sur des résultats issus d'un laboratoire universitaire. Quand on crée une société spin-off il y a des règles à respecter vis-à-vis de l'université pour pouvoir utiliser la propriété intellectuelle qui est issue des laboratoires.

Harry Usuwiel : Pourriez-vous nous expliquer plus en détail ce qu'est le FSO ?

Matthieu Palate : Il s'agit d'un fond de la région Wallonne qui permet de financer une personne pendant deux ans avec une possibilité d'une prolongation d'une troisième année dans laquelle on peut avoir un deuxième personnage qu'on appelle alter ego commercial et donc l'objectif de ce fond FSO c'est d'aider à la maturation technologique et économique d'un projet de recherche.

Harry Usuwiel : Quels sont les avantages d'une société spin-off par rapport à une simple start-up ?

Matthieu Palate : Fondamentalement il n'y a pas une grosse différence. Là où on va avoir des avantages de la spin-off par rapport à la start-up c'est d'avoir un label de l'université et avoir un support de l'université. Ça c'est un avantage que les start-up n'ont pas. En effet, tu vas créer cette société spin-off sur la propriété intellectuelle issue d'une université qui jouit d'une certaine réputation donc c'est un gage d'une certaine qualité vis-à-vis d'un investisseur. Si tu vas en tant que porteur spin-off devant des investisseurs pour obtenir du financement tu as potentiellement un peu plus de chance que quelqu'un qui est dans une start-up car tu as ce label universitaire. Tu bénéficies aussi d'un support financier d'une certaine manière de l'université par exemple via les fonds first spin-off qui

sont ouverts qu'aux universités. Là cela te permet d'avoir des fonds de maturation qui ne sont pas disponibles pour n'importe qui. Un autre avantage est le fait que l'université à Louvain on a la Sopartec qui est la société de transfert de technologie universitaire, qui gère également un fond d'investissement. Elle peut être encline à investir dans les projets de spin-off issue de l'université car elle les connaît et connaît leurs potentiels. Il y a aussi un encadrement qu'on peut obtenir grâce au LTTO, des gens qui vont accompagner le processus de création d'entreprise plus au niveau technologique mais aussi au niveau commercial.

Christophe Dumonceau : Il y a aussi un intérêt d'être adosser à l'UCLouvain pour pouvoir effectivement tester ton concept en salle d'opération. En effet, tu as une porte d'entrée au niveau des chirurgiens mais c'est toujours peut-être plus facile d'avoir déjà deux salles d'opérations qui sont déjà installées. Le deuxième élément, c'est certainement d'avoir un encadrement. C'est mon job aussi c'est d'encadrer les first spin-off où en tous cas certains d'entre eux pour démarcher d'autres hôpitaux ou cliniques. Par conséquent, le fait d'être UCLouvain auprès de ces autres hôpitaux c'est aussi un gros avantage. Ce qui est vraiment très important dans votre cas de figure car entre le temps de convaincre et le fait d'avoir l'argent sur son compte ça prend énormément de temps. Le timing FSO qui est deux ou trois ans vous permettra de ne pas devoir vivre sur vos propres moyens durant ces années-là.

Harry Usuiel : Quels sont les désavantages d'une société spin-off par rapport à une simple start-up ?

Matthieu Palate : Oui, il y a effectivement des inconvénients ça dépend de comment on le voit mais forcément qui dit propriété intellectuelle de l'université dit transfère. Généralement, on va avoir une parité des parts qui va appartenir à l'université et un accord de licence sur cette propriété intellectuelle. **Christophe Dumonceau :** Le tout est une question de choix stratégique. Vous avez l'option d'être 100% maître de votre société mais d'avoir peut-être plus de difficulté à lever des capitaux ou à effectivement rentrer sur le marché. Et puis, l'autre option c'est d'être assez dilué dès le départ mais d'être adosser et d'avoir l'aide de l'UCLouvain avec toujours la possibilité de trouver d'autres investisseurs par après qui rachèteraient les parts acquises initialement par l'UCLouvain.

Harry Usuiel : S'il y a un deuxième brevet qui est déposé par la spin-off est-il lui aussi considéré comme propriété intellectuelle de l'UCLouvain ?

Matthieu Palate : Si la spin-off continue à se développer et à développer de nouvelles choses c'est clair que c'est la spin-off qui en est propriétaire en tant que société. Prenez le cas d'IBA, la fondation de la société est basée sur un brevet UCLouvain sur une première version d'un cyclotron qu'on appelait le deep valley. Maintenant IBA, ils ont plusieurs

dizaines de brevet et cela appartient à IBA en tant que société et l'université a encore quelques parts d'en IBA mais je ne sais pas à hauteur de combien. Aujourd'hui les contrats de licence sont terminés et donc l'UCLouvain est actionnaire comme pleins d'autres acteurs.

E.0.7 Échange avec le Dr Lionel Benamran, Chirurgien Orthopédiste et Traumatologie

Harry Usuwiel: Après notre analyse de marché, nous avons pu identifier différents acteurs présents sur le marché mais qui ont disparu depuis. Avez-vous une idée du pourquoi ou des pistes ?

Dr Lionel Benamran: Aurais-tu des noms?

Harry Usuwiel: Pour les noms oui après des recherches nous sommes tombés sur différents acteurs qui n'ont plus l'air très actif :

- Gestsure - aeroTAP - STS - KiOP

Harry Usuwiel: Nous essayons d'identifier les décideurs au sein des hôpitaux. C'est une tâche assez compliquée quand on ne connaît pas du tout l'environnement. Pourriez-vous nous en dire plus afin que nous sachions où aller une fois le produit prêt ?

Dr Lionel Benamran: C'est les chefs de services que vous devez draguer et eux se charge du reste, rien ne se fait sans les chefs de service même si in fine c'est l'administration qui décide. Pour commencer je te propose d'aller voir le chef de service d'orthopédie d'Avicennes, il est très branché nouvelles technologies et il vous recevra avec plaisir. Une dernière chose: je pense qu'il serait plus judicieux de ne pas compter sur les hopitaux. C'est une machine lente et lourde. Allez voir plutôt les chirurgiens en clinique.

Harry Usuwiel: Pourquoi ne pas former les infirmières à ces programmes ? Pensez-vous qu'il y aurait une réelle valeur ajoutée pour vous de pouvoir contrôler ces images tout en maintenant la stérilité ?

Dr Lionel Benamran: il y a beaucoup d'infirmières différentes et elles se débrouillent finalement assez bien, c'est juste un peu plus long. Mais si l'outil est facile à utiliser, je suis preneur parce que je sais alors que je peux me fier à quelque chose que je contrôle et qui ne dépend pas de l'infirmière. une question à mon tour: je pourrais essayer votre outil?

Harry Usuwiel: Quel DICOM viewer utilisez-vous?

Dr Lionel Benamran: Pour l'immense majorité des orthopédistes que je connais, le lecteur d'images Dicom le plus populaire est OsiriX qui ne fonctionne que sur Mac. Si vous pouviez faire un plugin payant sur OsiriX vous auriez beaucoup d'utilisateurs.

E.0.8 Exchange with Professor Giovanni Saggio and Alex Calado from the University of Rome

Message from our Team

Dear Professor Saggio and Sir Calado,

The three students attached in this email and myself are writing our master thesis about the creation of a company that would help surgeons to control medical data through Gesture Recognition in the operating room. We are supervised by the professors Roselli and Vanderdonckt.

The Professor Roselli kindly gave us your contacts as you are applying a part of your researches in the corporate environment.

We would love to ask you the following questions and have your opinion on them. If you would agree to give us a bit of your time on those, we would be really grateful.

In your video with the sensory glove, the wearable allows the user to navigate on the computer: (1) Have you commercialised this project? How would you teach users to manipulate correctly the glove? (2) How would you evaluate the acceptance/open-mindedness of professionals for such devices to improve their business processes?

Our entrepreneurial project would need surgeons to learn the different gestures related to the different commands to navigate into the system. To capture the surgeon gestures, we were thinking to use the Leap Motion as sensor. (3) Would you recommend another sensor that could be more suitable? (4) What is your opinion on our project?

Respectfully, Tancredi d'Aspremont, Bastien Nothomb, Harry Usui et Jean Wilberz

Answer from Alex Calado

Dear Jean,

Thank you for your email and congrats for your interesting project.

I will let Professor Saggio answer your first question.

Regarding your second question: If wearable devices are not an option for you, leap motion looks like a good approach in my opinion, however take into account its limited operating range, i guess it depends exactly how the surgeon will use the system. From the top of my mind, i can think of Kinect or Intel RealSense+Nuitrack (both also have a larger operating distance) as possible alternatives to leap motion. In a review i found comparing leap motion and kinect (attached) it seems the first one provides a more accurate tracking

than kinect. However, leap motion only tracks the hands and the kinect provides a full mapping of the whole body. I guess the same thing can be observed for the intel realsense.

I've also found one article that used both sensors, separately, for gesture detection and another article that used leap motion for an application similar to yours. I've attached both, as they can be useful for you.

I'm at your disposal if you have any more questions.

Best, Alex

Answer from Professor Saggio

Answers to the questions: (1) No we have not. With supervised training. (2) With a questionnaire. (3) Yes, IMUs to be dressed. (4) Interesting, for sure.

E.0.9 Exchange with Mr Sakamoto from aeroTAP

Our solution aeroTAP Evolution enables surgeon to navigate existing DICOM viewer without keyboard and mouse. There are several kind of DICOM viewer. If the existing system is running on Windows system. You just need aeroTAP Camera and aeroTAP Evolution software to transform it to touchless system. For medical solution, aeroTAP Evolution needs "Pro" License. It costs 500USD which includes aeroTAP Camera and aeroTAP Evolution Pro license. For generic use (non-commercial use), aeroTAP Evolution is free for aeroTAP Camera. It costs 225USD + 30USD(Shipping fee), We also provides fee based consultant service to customize aeroTAP Evolution settings for their DICOM system. - It is simple customization to add some virtual buttons for Display Scrolling or Mouse Wheel actions. - May be you can handle such service n locally once you understand aeroTAP's assistant features (virtual buttons). For more detail, please check Online User's Guide here: <http://www.aeroTAP.com/Help>

—

Sorry, our 3D cameras do not have a microphone. If you have any further questions, please let us know. Regards, T.Sakamoto

APPENDIX

F

CONTRACTS

F.0.1 Civil Responsibility Insurance and Other Complementary Insurances

Courtier: AAA CAPITALASSUR
 N° : 62773
 Références: RICARDO
 N° FSMA: 0713631473
 Téléphone: 02/5170211
 Fax: 02/5170200

RESPONSABILITÉ CIVILE

OFFRE N° 2606044

DESCRIPTION DE L'ACTIVITE

Bureau d'études, d'ingénierie dans le secteur médical

DATE D'EFFET

Situation du risque

PRIMES

	Taux de calcul	Base de tarification	Prime sans taxes	Prime avec taxes
Garantie exploitation				
Associés : 5	0,12000%	29.579,81 salaire conventionnel égal à 0,66 fois le maximum légal	177,48	193,90
Garantie responsabilité professionnelle				
	0,60000%	250.000,00 chiffre d'affaires	1.500,00	1.638,75
Protection juridique				
		prime fixe	32,00	34,96
PRIME ANNUELLE TOTALE			1.709,48	1.867,61
PRIME ANNUELLE TOTALE avec taxes et frais avec réduction Modulis				1.680,85

GARANTIES

Garantie exploitation		
Dommages corporels et dommages matériels confondus	1.500.000,00 EUR	par sinistre
Franchise	10%	par sinistre
	avec un minimum de 250,00 EUR et un maximum de 1.250,00 EUR	
Garantie responsabilité professionnelle		
RC Professionnelle		
Dommages corporels, matériels & immatériels confondus	250.000,00 EUR	par sinistre et par année d'assurance
Franchise	10%	par sinistre
	avec un minimum de 250,00 EUR et un maximum de 2.500,00 EUR	
Protection juridique		

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Courtier N°: 62773
Nom Preneur: JEANWILDBERG

CL. 893 : LA GARANTIE RESPONSABILITE PROFESSIONNELLE

Les dispositions prévues ci-dessous complètent les garanties ''R.C. Exploitation'' et ''R.C. Objet confié'' des Conditions Générales ''Formule R.C.'' et les conditions particulières de votre contrat. Elles les annulent et les remplacent en cas de contradiction.

Les présentes dispositions annulent et remplacent ''R.C. Après Livraison'' des Conditions Générales ''Formule R.C.'' Elles ne s'appliquent que si la garantie ''Après Livraison'' de la formule R.C. n'est pas d'application.

Article 1 : Le risque assuré La Compagnie garantit l'assuré, dans les limites fixées aux conditions générales et particulières, contre les conséquences pécuniaires de sa responsabilité civile contractuelle et extracontractuelle du fait de dommages causés à des tiers par ses fautes professionnelles sous toutes ses formes, telles qu'elles sont définies par les dispositions légales et réglementaires en droit belge et étranger, en vigueur au moment du sinistre.

Par faute professionnelle, il faut entendre tout manquement à des engagements, toute négligence, erreur, inexactitude ou déclaration qui induit en erreur, toute omission et tout acte fautif commis par l'assuré dans l'exercice de ses activités professionnelles telles que décrites en conditions particulières.

Article 2 : l'étendue dans le temps et l'étendue territoriale de la couverture Nous vous assurons pour tout dommage survenu pendant la durée du contrat.

Nous vous assurons pour tout dommage survenu dans le monde entier dans le cadre des activités assurées de vos sièges d'exploitation établis en Belgique.

Toutefois, pour les travaux exécutés aux États-Unis d'Amérique ou au Canada nous ne vous assurons que moyennant une déclaration préalable de votre part et après acceptation écrite de notre part. Les voyages d'affaires, la participation à des réunions ou à des séminaires sont couverts d'office, sans égard au lieu où ils se tiennent.

Article 3 : Les dommages assurés L'assurance garantit l'indemnisation :

-des lésions corporelles -des dommages matériels -des dommages immatériels.

Article 4 : Les limitations de garantie Dans le cadre de votre responsabilité professionnelle et en complément aux exclusions communes des conditions générales de la Formule RC, nous ne vous assurons pas pour:

- 1.les frais exposés par l'assuré pour recommencer et/ou corriger le travail exécuté ;
- 2.la responsabilité décennale des architectes et entrepreneurs ou les responsabilités similaires selon le droit belge ou étranger ;
- 3.1'insolvabilité de l'assuré et/ou de ses associés ;
- 4.les contestations relatives au paiement de frais et honoraires, ainsi qu'au dépassement de devis ;
- 5.des engagements particuliers consentis par les assurés et qui aggravent leur responsabilité civile telle qu'elle résulte des textes légaux et en tout état de cause, la prise en charge de la responsabilité du fait d'autrui, les pénalités conventionnelles, les abandons de recours ;
- 6.les demandes en réparation du dommage résultant du droit applicable sur les territoires des USA et du Canada ou introduites dans le ressort des juridictions ou sur les territoires de ces états ;
- 7.le seul fait de la non-exécution ou du retard d'exécution d'une prestation ;
- 8.des avis financiers et économiques en matière de conjoncture ou de situation de marché, ainsi que de services financiers, gestion financière, placements en argent ou en valeurs ;
- 9.la responsabilité personnelle des sous-traitants de l'assuré ;
- 10.la rupture de négociations préalables à la signature d'un contrat ou de la rupture unilatérale d'un contrat ;
- 11.la divulgation de faits dont les assurés ont connaissance de par leur fonction et/ou de secrets professionnels ;

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12.tous dommages résultant du fait que le résultat recherché n'a pas été atteint ou du fait que les produits ou ouvrages, quoique correspondant aux normes et procédés de fabrication, n'ont pas l'efficacité ou le rendement promis ;

13.des prestations qui n'entrent pas dans le cadre des activités professionnelles décrites en conditions particulières ;

14.des dommages qui relèvent des garanties R.C.Exploitation, R.C. après livraison ou R.C. objet confié ;

15.les dommages causés intentionnellement;

16.Tout dommage causé en état d'ivresse, d'intoxication alcoolique légale, sous l'influence de stupéfiants ou à l'occasion de paris ou de défis, à moins que vous ne soyez en mesure d'établir qu'il n'existe aucun lien causal entre ces états et le sinistre.

17. Les dommages découlant de l'exercice de l'activité assurée sans disposer des agréments et / ou des qualifications légalement requis(es).

CL. JCF : DOMMAGES IMMATERIELS

Les dommages immatériels sont limités à 25 % du montant du capital prévu pour les dommages matériels, sans que ce montant puisse être inférieur à 250.000 EUR.

Si les capitaux prévus pour les dommages corporels et les dommages matériels sont confondus, les dommages immatériels sont limités à 25 % du capital confondu.

REMARQUES

La présente tarification est émise sous réserve de la proposition RC Consultants complétée ainsi que du numéro de BCE attribué au client

Le calcul de la prime est basé sur un chiffre d'affaire fictif et ce, sous réserve de celui réellement d'application

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Formule 24

Vie professionnelle et vie privée

OFFRE N° 2606044

DESCRIPTION DE L'ACTIVITE

Bureau d'études, d'ingénierie dans le secteur médical

ASSURE

Assuré identique au preneur: Non

assuré 1

N°:

Boîte:

DATE D'EFFET

INFORMATIONS TARIFAIRES GENERALES

Rémunération annuelle conventionnelle: 5.000,00 EUR

GARANTIES ET PRIMES

✓	Incapacité temporaire de travail	Indemnité maximale : 13,70 EUR par jour Indemnisation après un délai de carence de 7 jours	49,17	EUR
✓	Décès	25.000,00 EUR (5 fois la rémunération annuelle assurée)	16,32	EUR
✓	Invalidité permanente	Max. 50.000,00 EUR (10 fois la rémunération annuelle assurée)	50,52	EUR
✓	Frais médicaux	Après intervention de la sécurité sociale, intervention maximale de 2.500,00 EUR (0,5 fois la rémunération annuelle assurée) avec une franchise de 150,00 EUR	15,00	EUR
✓	Moto : couvert à raison de 50 % des garanties			
	PRIME NETTE ANNUELLE (sans taxes)		131,01	EUR
	PRIME ANNUELLE TOTALE (taxes comprises)		143,13	EUR
	PRIME ANNUELLE TOTALE avec taxes et frais avec réduction Modulis		128,82	EUR

ANTECEDENTS

Le client a-t-il déclaré plus d'un sinistre au cours des 5 dernières années pour les garanties choisies?

REMARQUES

La présente tarification est émise sous réserve des coordonnées précises de la personne à assurer ainsi que de ses antécédents sinistres

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Courtier : AAA CAPITALASSUR
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SYNTHESE MODULIS

OFFRE N° 2606044

PRENEUR

JEANWILDBERG
 Place de l'Université
 B 1348

N°: 1
 Louvain-l-Neuve

Boîte:

Importance : < 10 personnes

ACTIVITE

Bureau d'études, d'ingénierie dans le secteur médical

ECHEANCE 01-01

ASSURANCES ET PRIMES

✓ Assurance de base	Date d'effet	Prime annuelle sans réduction Modulis ¹	Prime annuelle avec réduction Modulis ¹
✓ Responsabilité civile		1.867,61	1.680,85
✓ Formule 24: Vie professionnelle et vie privée assuré 1		143,13	128,82

PRIME TOTALE ANNUELLE (en EUR)

2.010,74

1.809,67

Cette offre a été rédigée en fonction des données en notre possession et sous réserve des antécédents.
 Elle est valable pour une période de 30 jours.

Les données à caractère personnel recueillies dans ce document sont traitées par AG Insurance SA, ayant son siège social à 1000 Bruxelles, Boulevard Emile Jacqmain 53 (ci-après, "AG Insurance"), en tant que responsable du traitement, conformément au Règlement (UE) 2016/679 du Parlement Européen et du Conseil du 27 avril 2016 relatif à la protection des personnes physiques à l'égard du traitement des données à caractère personnel et à la libre circulation de ces données, ainsi qu'à la Notice Vie Privée d'AG Insurance sur le site web www.aginsurance.be.

Ces données sont traitées pour les finalités mentionnées dans la Notice Vie Privée d'AG Insurance et en particulier pour :

- la gestion et l'exécution des services d'assurance, en ce compris la gestion de la relation clientèle et ce sur base de l'exécution du contrat
- réaliser toute finalité imposée à AG Insurance par une disposition légale, réglementaire ou administrative, et ce sur base de cette disposition
- l'analyse des données, l'établissement de statistiques, de modèles et de profils, la détection et la prévention des abus et de la fraude, la constitution de preuves, la sécurité des réseaux et systèmes informatiques d'AG Insurance, la sécurité des biens et des personnes, l'optimisation des processus (par exemple d'évaluation et d'acceptation du risque, des processus internes, etc.), le développement de nouveaux produits, la prospection ainsi que, le cas échéant, le profilage et la prise de décisions sur base d'un profil pour les finalités mentionnées ci-avant, et ce sur base de l'intérêt légitime d'AG Insurance.

Dans certains cas, vos données peuvent également être traitées avec votre consentement.

Ces données pourront être communiquées le cas échéant à d'autres entreprises d'assurances intervenantes, à leurs représentants en Belgique, à leurs correspondants à l'étranger, aux entreprises de réassurance concernées, à des bureaux de règlement de sinistres, à un expert, à un avocat, à un conseil technique, à votre intermédiaire d'assurances ou à un sous-traitant. Les données peuvent également être communiquées à toute personne ou instance dans le cadre d'une obligation imposée par la loi ou une décision judiciaire ou administrative. AG Insurance est susceptible de transmettre vos données en dehors de l'Espace économique européen (EEE), dans un pays qui n'assure pas un niveau de protection adéquat des données à caractère personnel. Dans ce cas, AG Insurance renforce davantage la sécurité informatique et exige contractuellement un niveau de sécurité renforcé de la part de ses contreparties internationales.

Les données traitées sont conservées pendant toute la durée du contrat d'assurance, la période de prescription légale ainsi que tout autre délai de conservation qui serait imposé par la législation et la réglementation applicables.

Dans les limites fixées par la réglementation vous avez le droit de prendre connaissance de vos données, le cas échéant, de les faire rectifier, et d'en demander la communication à des tiers, vous avez le droit de vous opposer au traitement de vos données, le droit de demander la limitation du traitement de celles-ci ainsi que le droit à leur effacement. Dans ces cas, AG Insurance pourrait se trouver dans l'impossibilité de poursuivre la relation contractuelle.

Vous pouvez exercer vos droits au moyen d'une demande datée et signée accompagnée d'une photocopie recto verso de votre carte d'identité à envoyer par courrier à AG Insurance,

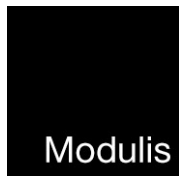
¹ avec taxes et cotisations, aux indices d'application au moment de l'offre.

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Contact : Bd Tirou 185, B-6000 Charleroi - Tel. +32(0)71 27 62 11 - Fax +32(0)71 27 62 50



Courtier N°: 62773
Nom Preneur: JEANWILDBERG

Data Protection Officer, 1000 Bruxelles, Boulevard Emile Jacqmain 53, ou par email à : AG_DPO@aginsurance.be. Une réclamation peut le cas échéant être introduite auprès de l'Autorité de protection des données.
Plus d'informations peuvent être obtenues à la même adresse ainsi que dans la Notice Vie Privée d'AG Insurance sur le site web www.aginsurance.be.

Fait à Bruxelles

11/05/2020

Accord pour confection des pièces

Signature

F.0.2 Associates Agreement

PACTE D'ASSOCIÉS

Entre les associés de l'entreprise : **Guinevere**
En date du 11/05/2020

ENTRE

€ **Tancrède d'Aspremont**
€ **Bastien Nothomb**
€ **Harry Usuwiel**
€ **Jean Wilberz**

Tous associés de la potentielle future entreprise **Guinevere SRL**.

Ci-après désignés individuellement une " Partie " et collectivement les " Parties ".

IL EST PRÉALABLEMENT EXPOSÉ CE QUI SUIV

Les parties au présent Pacte sont associés de l'entreprise **Guinevere**.
Les Parties ont exprimé leur volonté de contribuer le plus efficacement possible au développement de l'entreprise dont ils sont associés, et sont donc convenues d'organiser par le présent Pacte leurs relations et leurs accords à propos de la gouvernance de l'entreprise.
Le présent Pacte entrera en vigueur le jour de sa signature.

EN CONSÉQUENCE DE QUOI IL A ÉTÉ CONVENU CE QUI SUIV

TITRE 1 - DISPOSITIONS GÉNÉRALES

ARTICLE 1 - DÉFINITIONS

Dans le présent Pacte d'associés, les mots et expressions suivants ont le sens qui leur est attribué ci-dessous :

- **Parts sociales** : titres de propriété portant sur le capital de l'entreprise, et les droits rattachés à ceux-ci.
- **Pacte** : fait référence au présent Pacte d'associés, signé par chacune des Parties. Il pourra éventuellement être modifié par avenant signé par l'ensemble des Parties.
- **Parties** : désigne l'ensemble des associés ayant adhéré aux présentes.
- **Entreprise** : fait référence à l'entreprise **Guinevere** dans laquelle les Parties détiennent des parts sociales.
- **Tiers** : toute personne physique ou morale non signataire ou n'ayant pas adhéré aux présentes.
- **Titres** : tout titre de quelque nature qu'il soit, représentatif d'une quotité du capital de l'entreprise ou donnant droit, directement ou indirectement, de

façon immédiate ou différée, notamment par voie de conversion, d'échange, de remboursement, de présentation d'un bon ou de quelque manière que ce soit, à l'attribution d'un titre représentatif d'une quotité du capital ou de droits de vote de l'entreprise, et tout bon ou droit à la souscription ou à l'attribution d'un titre tel que présentement défini ainsi qu'à tous droits cessibles ou négociables susceptibles d'être détachés des Titres de l'entreprise.

- **Transfert** : toute opération, toute mutation, transfert ou cession d'une ou plusieurs parts sociales à caractère gratuit ou onéreux et ce, quel qu'en soit le mode juridique. Ces opérations comprennent notamment et sans que cette énumération soit limitative, la négociation en bourse ou hors bourse, la vente publique ou non, l'apport à une offre publique d'achat ou d'échange, l'échange, l'apport en société y compris à une société en participation, la fusion, la scission, ou toutes opérations assimilées, la donation, le transfert de nue-propriété ou usufruit, le prêt, la constitution d'une garantie, la convention de croupier, etc., de tout ou partie des Titres, en propriété, en usufruit ou en nue-propriété, qui sont ou deviendraient la propriété des associés.

ARTICLE 2 - OBJET DU PACTE

L'objet du présent Pacte est de définir les droits et obligations des Parties et leurs engagements respectifs au regard de leur qualité d'associés de l'entreprise

Guinevere, en vue de la poursuite d'objets communs au travers de l'entreprise.

l'entreprise **Guinevere** est immatriculée à la Banque Carrefour des Entreprises de sous le numéro _____ (**A COMPLETER** lors de la création de la société). Etant donné le léger changement du contrat, un paraphe de chacune des Parties sera nécessaire une fois le numéro ajouté.

Paraphes des Parties:

Les Parties déclarent bien connaître l'activité de cette entreprise, et ont exprimé leur volonté de contribuer le plus efficacement possible au développement de l'entreprise.

A travers le présent Pacte, les Parties souhaitent ainsi consigner leurs accords à propos de la gouvernance de l'entreprise et de leurs relations en qualité d'associés de celle-ci.

L'objet du Pacte est donc de définir les droits et obligations des Parties, notamment au regard des Titres, et les termes et conditions qu'elles acceptent de respecter pendant sa durée de validité en vue de la poursuite de leurs objectifs communs à travers l'entreprise.

Les droits issus du présent Pacte porteront sur la totalité des Titres détenus par les Parties, et sur tous ceux qu'elles viendraient à détenir ultérieurement, notamment par l'exercice d'un droit de préemption.

Les Parties acceptent de respecter les termes et conditions du présent Pacte pendant l'ensemble de sa durée.

ARTICLE 3 - DÉCLARATION

Chaque Partie au présent Pacte déclare et garantit qu'elle a la capacité de signer et d'exécuter le Pacte, et le cas échéant que la signature et l'exécution du Pacte ont été valablement autorisées par ses organes compétents.

Les stipulations du présent Pactes prévaudront sur celles des statuts de l'entreprise pour les Parties en cas de contradiction.

TITRE 2 - CAPITAL ET TRANSFERTS DE TITRES

ARTICLE 4 - DISTRIBUTION DES DIVIDENDES

Les Parties s'engagent, pendant toute la durée de détention des Titres de capital de l'entreprise, à tout mettre en œuvre pour que l'entreprise adopte une politique de distribution des dividendes aux associés.

A ce titre, elles s'engagent à faire usage de leur droit de vote en tant qu'associés de l'entreprise afin de voter favorablement aux résolutions allant dans ce sens qui leur seront présentées, notamment lors des assemblées générales concernant l'affectation du résultat de l'exercice passé.

Les Parties s'engagent également à toujours faire passer le bien social des parties prenantes autour de l'entreprise **Guinevere** avant l'intérêt pécunier que peuvent avoir les détenteurs de titres.

ARTICLE 5 - ASSEMBLÉE GÉNÉRALE

Droit de vote

Lors de toute assemblée générale de l'entreprise **Guinevere**, visant à réunir l'ensemble des associés détenant des Titres, les Parties devront exercer leur droit de vote s'attachant à leurs Titres afin de prendre toutes les mesures nécessaires pour donner effet aux dispositions du présent Pacte.

Ce faisant, ils devront prendre toutes les mesures nécessaires afin de garantir que les statuts de l'entreprise n'entrent pas en conflit avec les dispositions du présent Pacte.

Les Parties devront ainsi voter et agir en conformité avec les termes et dispositions spécifiques du présent Pacte, notamment en ne votant pas pour une disposition ou amendement qui pourrait entrer en conflit avec le Pacte, ou prétendrait modifier ou remplacer toute disposition du Pacte.

Elections

Pour donner effet au présent Pacte, chaque Partie devra faire en sorte, si un vote est prévu au cours d'une assemblée générale, d'exercer son droit de vote afin de favoriser le présent Pacte et les autres Parties.

Chaque Partie devra ainsi prendre les mesures nécessaires afin de garantir l'élection de personnes désignées par l'ensemble des Parties au présent Pacte.

ARTICLE 6 - TRANSFERT DE TITRES ENTRE LES PARTIES

Le transfert de Titres entre les Parties est libre.

Tout transfert à des Tiers sera subordonné aux conditions décrites ci-après.

ARTICLE 7 - CLAUSE DE SORTIE CONJOINTE

Les associés Parties au présent Pacte qui détiennent la majorité des parts sociales du capital de l'entreprise s'engagent à ne pas céder leurs titres sans donner aux associés minoritaires la possibilité d'en faire autant et aux mêmes conditions.

Chaque Partie décidant à ce titre de procéder à la cession de ses Titres devra adresser une notification de sortie conjointe à l'ensemble des autres Parties qui sont

titulaires de ce droit de sortie conjointe, les informant de chaque cession de Titre qu'elle se propose d'effectuer et qui donne naissance aux droits des titulaires du droit de sortie conjointe. Cette notification devra indiquer le nom de l'associé vendeur, le nombre de titres devant être cédés au Tiers acquéreur, ainsi que l'identité du-dit Tiers.

Le Tiers acquéreur a été informé par la Partie cédante des droits de sortie conjointe stipulés à la présente clause, et s'est obligé à acquérir des Titres conformément aux dispositions des présentes.

Si les Parties au présent Pacte titulaire du droit de sortie conjointe ne se manifestent pas dans un délai et sous une forme raisonnable, elles seront réputées avoir renoncé à leurs droits.

ARTICLE 8 - CLAUSE D'ENTRAÎNEMENT OU CESSION FORCÉE

Les associés minoritaires Parties au présent Pacte s'obligent à céder leurs actions au Tiers cessionnaire choisi par les associés majoritaires Parties au présent Pacte. Ainsi, les associés majoritaires auront le droit d'exiger que les associés minoritaires vendent leurs Titres au(x) Tiers acquéreur(s) aux mêmes termes et conditions qu'eux.

Si les associés majoritaires souhaitent exercer leur droit de cession forcée, ils devront en informer les associés minoritaires par une notification de cession forcée, dans un délai de cinq (5) jours ouvrés au moins avant la date à laquelle la cession doit avoir lieu, en indiquant le nombre de Titres cédés, l'identité du Tiers acquéreur et le montant ainsi que les modalités de paiement.

Le Tiers acquéreur, dans le cas d'une application de ce droit de cession forcée, a été informé de ce droit et s'est obligé à acquérir les Titres conformément aux dispositions des présentes.

ARTICLE 9 - TITRES NOUVEAUX

Les Parties au présent Pacte s'engagent de faire en sorte que l'entreprise n'émette aucun Titre pour un prix inférieur à leur juste valeur de marché.

De plus, les Parties devront faire en sorte que l'entreprise, en cas d'émission de nouveaux Titres en numéraire, accorde aux Parties au présent Pacte un droit de préemption sur ces Titres.

ARTICLE 10 - CLAUSE D'AGREMENT

La cession des Titres donnant accès au capital est soumise à l'agrément de l'ensemble des Parties. Ainsi, une Partie qui souhaite céder, de quelque manière que ce soit, la totalité ou une partie de ses Titres à un Tiers aux présentes, doit au préalable notifier son projet de cession à l'ensemble des autres Parties aux présentes.

Cette notification doit indiquer l'identité et l'adresse du Tiers cessionnaire, le nombre de Titres dont la cession est envisagée, le prix de cession ainsi que les principales conditions de la cession. Cette notification vaudra offre de cession au profit de toutes les autres Parties aux présentes.

Pour que la cession des Titres soit autorisée à un Tiers, il est nécessaire que l'unanimité des Parties approuve le projet de cession. Cette approbation devra au plus tard intervenir dans les trente (30) de la notification. L'absence de réponse quant au projet de cession de l'une des Parties vaudra approbation de la cession. En cas de refus de la cession par l'une des Parties, celle-ci sera tenue d'acquérir les Titres concernés par le projet de cession.

Ce pacte étant repris d'une base de pacte d'associés français, il fait référence à l'Article L. 228-23 du Code de Commerce français. S'il existe un équivalent dans la législation belge, la clause de l'article 10 ne pourra s'appliquer dans les cas de succession, de liquidation du régime matrimonial ou de cession, soit à un conjoint, soit à un ascendant ou à un descendant.

ARTICLE 11 - DROIT DE PRÉEMPTION

Chacune des Parties au présent Pacte consent aux autres Parties, dans le cadre d'un projet de Transfert, un droit de préemption sur les Titres transférés, aux mêmes termes et conditions que ceux prévus dans le projet de Transfert.

Ainsi, les Parties s'interdisent pendant toute la durée de validité du présent Pacte de céder leurs Titres à des Tiers avant de les avoir préalablement offerts aux autres Parties du présent Pacte.

Le droit de préemption ne pourra s'exercer valablement qu'à la condition que les Parties souhaitant en bénéficier aient fait connaître leur intention de l'exercer dans un délai et sous une forme raisonnable.

En cas d'exercice du droit de préemption, la répartition des Titres entre les Parties souhaitant en bénéficier se fera au prorata du nombre de parts sociales qu'elles détiennent dans le capital de l'entreprise.

TITRE 3 - ORGANES INSTITUÉS PAR LE PACTE

ARTICLE 12 - NOMINATION D'UN DIRIGEANT

Les Parties aux présentes décident de procéder à la nomination du dirigeant de l'entreprise.

Il est ainsi décidé de nommer en tant que dirigeant de l'entreprise **Guinevere : Jean Wilberz**.

TITRE 4 - GESTION DU PACTE ET STIPULATIONS DIVERSES

ARTICLE 13 - CLAUSE DE CONFIDENTIALITÉ

Chacune des Parties s'engage à considérer le présent Pacte comme strictement confidentiel. Les Parties s'engagent à ne pas céder, divulguer ou transférer à un Tiers tous documents et informations acquis dans le cadre de la mise en œuvre et du respect du présent Pacte, ou concernant toutes questions liées à l'activité, à la technologie et aux affaires financières de l'entreprise, qui pourrait revêtir un caractère sensible ou confidentiel sur le plan concurrentiel.

Cette clause de confidentialité ne s'applique pas pour les cas précis où l'ensemble des Parties choisit, à l'unanimité, de divulguer certaines des informations relatives au présent Pacte, ou lorsqu'il s'agit de divulgations faites à un administrateur, cadre, salarié ou conseil professionnel d'une des Parties, mais seulement en vue de l'exécution par cette Partie de ses engagements et obligations ou de l'exercice de ses droits résultant de sa participation dans l'entreprise et de son engagement dans le présent Pacte, et si l'administrateur, cadre, salarié ou conseil professionnel susvisé s'engage préalablement à respecter le même engagement de confidentialité, ce dont cette Partie se portera fort.

Ne sont toutefois pas tenues pour confidentielles les informations :

- Tombées ou qui tomberont dans le domaine public du fait de Tiers et sans négligence de la part de la Partie ayant divulgué l'information,
- Dont une Partie a eu ou aura connaissance sans violation du présent engagement de confidentialité,
- Dont la loi ou toute citation judiciaire exigent qu'elles soient rendues publiques.

Il est entendu que dans ces cas exceptionnels, la Partie divulguant ces informations devra déployer des efforts raisonnables pour notifier préalablement cette divulgation aux autres Parties, notamment si la divulgation doit se faire sous la forme d'une annonce en vertu d'une exigence de la loi, auquel cas la Partie devra, avant de faire la-dite annonce, adresser le projet de cette annonce aux autres Parties afin de leur donner une possibilité raisonnable de formuler des commentaires sur ce projet.

ARTICLE 14 - CLAUSE DE NON-CONCURRENCE ET D'EXCLUSIVITÉ

Les Parties au présent Pacte s'engagent, sur toute la durée pendant laquelle elles seront propriétaires de Titres de l'entreprise, et sur la période suivante : deux ans, à compter de la date à laquelle elles n'auront plus la qualité d'associés de l'entreprise :

- À ne pas participer, être intéressé, se consacrer, directement ou indirectement, à quelque titre que ce soit et notamment en tant que mandataire social, actionnaire, associé, mandant, employé, consultant ou autre, à la création, l'exploitation ou la prise de participation d'une entité dont l'activité est en concurrence directe ou indirecte avec les activités de l'entreprise ;
- À ne pas entreprendre par l'intermédiaire de toute personne qui lui serait liée à quelque titre que ce soit, toute activité venant également concurrencer directement ou indirectement les activités de l'entreprise.

Cette clause de non-concurrence se limite à la zone géographique suivante : Europe, Amérique et Asie.

De plus, les Parties s'engagent à se consacrer à la bonne exécution du présent Pacte, et au profit de l'activité de l'entreprise. Ils exerceront toutes diligences requises à l'accomplissement de leurs fonctions.

ARTICLE 15 - ADHÉSION AU PACTE

Tout transfert de titres de l'entreprise au profit d'un Tiers sera subordonné à son adhésion au présent Pacte.

Ainsi, chacune des Parties souhaitant procéder à un transfert de ses parts sociales au profit d'un Tiers au Pacte devra faire en sorte que préalablement audit transfert, le Tiers ait adhéré sans réserve au présent Pacte, en vertu d'un écrit notifié à l'ensemble des Parties.

A défaut pour le Tiers d'avoir adhéré au Pacte dans un délai de dix (10) jours à compter de la réalisation du Transfert, la Partie cédante devra verser aux autres Parties une indemnité égale au prix des titres cédés. Cette indemnité sera partagée par les Parties en proportion de leur pourcentage de capital détenu par chacune d'entre elles.

Ledit Tiers deviendra partie au Pacte une fois celui-ci signé. Une copie du Pacte ainsi modifié sera alors notifiée à chacune des Parties.

ARTICLE 16 - DROIT A L'INFORMATION DES PARTIES

Les Parties aux présentes s'engagent mutuellement à rechercher toutes les informations nécessaires sur l'entreprise, afin de pouvoir notamment exprimer leurs votes en pleine connaissance de cause.

Les Parties ayant accès aux informations essentielles de l'entreprise se portent fort de la transmission aux autres Parties d'une copie des tableaux de bord de l'entreprise, avec ses commentaires sur l'activité comprenant au minimum les informations suivantes :

- Le chiffre d'affaires
- Les charges
- L'effectif
- Les éléments de comparaison avec le budget prévisionnel

Dans le courant du dernier trimestre de l'exercice social de l'entreprise, un budget prévisionnel détaillé pour l'exercice suivant devra être transmis aux Parties.

Les Parties pourront ainsi, à leur frais, faire procéder à l'audit des comptes annuels de l'entreprise.

ARTICLE 17 - MODIFICATION DU PACTE

Le présent Pacte ne pourra être modifié que par accord écrit et signé par chacune des Parties. Cette modification à l'unanimité fera l'objet d'un avenant au Pacte.

Ainsi, aucun amendement, aucune adjonction ni aucune modification ne pourra valablement être apporté au présent Pacte sans être constaté par un acte écrit et signé ou paraphé par chacune des Parties aux présentes, sous peine d'être privé d'effet. Il en sera de même de toute renonciation, et de tout consentement d'une partie à déroger à l'une quelconque des stipulations du présent Pacte.

ARTICLE 18 - SANCTIONS DE L'INOBSERVATION DU PACTE

Les Parties au présent Pacte sont informées de la responsabilité contractuelle découlant de ce Pacte. Ainsi, elles sont informées qu'en cas d'inobservation du Pacte dans les modalités prévues ci-contre, leur responsabilité sera engagée entraînant pour elles le paiement de dommages-intérêts envers les Parties lésées. De plus, tout acte passé en violation du présent Pacte sera annulé s'il est frauduleux.

Les Parties entendent donc que chacune d'entre elles ait le droit de solliciter des dommages-intérêts ou l'exécution en nature si toute autre Partie manque d'exécuter ses obligations aux termes des présentes.

ARTICLE 19 - DURÉE ET FIN DU PRÉSENT PACTE

Le présent Pacte prend effet à compter de sa signature et s'imposera aux Parties tant qu'elles demeureront associées de l'entreprise **Guinevere**.

Le Pacte étant conclu pour une durée indéterminée, chaque Partie sera libre d'y mettre fin à tout moment, sous réserve de respecter le délai de préavis suivant : un mois.

Toutefois le Pacte sera résilié par anticipation dans les cas suivants :

- En cas d'introduction en bourse de l'entreprise sur un marché réglementé ;
- Par accord unanime des Parties pour y mettre fin.

L'expiration du Pacte ne sera cependant d'aucun effet sur la validité de tout droit ou toute obligation d'une Partie, né(e) du fait de l'exécution ou de l'inexécution du Pacte préalablement à son expiration. De la même manière, l'expiration du Pacte ne sera d'aucun effet sur tout litige en cours portant sur l'inexécution ou la violation d'obligations contractuelles par l'une des Parties aux présentes.

ARTICLE 20 - TRANSFERT DES DROITS ET OBLIGATIONS AUX HÉRITIERS

Le présent Pacte liera valablement et bénéficiera aux héritiers, aux légataires et ayants droit, ainsi qu'aux représentants légaux de chacune des Parties, à l'exclusion des cessionnaires autres que ceux autorisés.

Aucune personne autre que les Parties aux présentes et leurs successeurs n'est destinée à être bénéficiaire du présent Pacte.

ARTICLE 21 - NOTIFICATIONS

Sauf dispositions contraires, toutes les notifications seront valablement faites à partir du moment où chacune des Parties en aura pris connaissance, quelque que soit le média de communication. Un email comprenant chaque Partie en copie carbone est suffisant par exemple.

ARTICLE 22 - AUTONOMIE DES DISPOSITIONS CONTRACTUELLES

La nullité, l'annulation ou la non-application de l'une ou de plusieurs clauses du présent Pacte, pour quelque motif que ce soit, n'entraînera pas la nullité de l'ensemble du Pacte.

Ainsi, dans le cas où une ou plusieurs des dispositions du présent Pacte seraient nulles et non avenues, annulées ou s'avèreraient inapplicables, la validité, la légalité et l'applicabilité des autres dispositions n'en seraient aucunement affectées ou atteintes.

Les Parties s'engagent également à se concerter pour remédier à la cause de nullité constatée de sorte que le Pacte puisse poursuivre ses effets sans discontinuité.

ARTICLE 23 - AUTRES DISPOSITIONS

Les Parties conviennent que le présent Pacte représente l'intégralité de leur accord quant à son objet, et remplace, annule et prévaut sur toutes conventions ou documents antérieurs ayant un objet identique ou semblable à celui du Pacte.

Les stipulations faites en préambule et dans d'éventuelles annexes font partie intégrante du Pacte, et ont par conséquent la même force obligatoire que le Pacte.

Les Parties s'engagent à communiquer, à signer et à délivrer toutes informations et tous documents nécessaires, ainsi qu'à passer tous actes ou à prendre toutes décisions qui pourraient être nécessaires à l'exécution du Pacte.

Le fait pour une Partie de ne pas se prévaloir de l'un des droits lui étant conférés par le présent Pacte ne vaudra pas renonciation de la part de cette Partie à la possibilité de se prévaloir ultérieurement de ce droit, si les conditions de son exercice se trouvent à nouveau réunies.

Enfin, les Parties reconnaissent expressément le caractère irrévocable et intangible des termes du Pacte. Toute manifestation de volonté de la part de l'une d'entre elles visant à affecter les termes et conditions du Pacte sera privée de tout effet si elle se fait sans le consentement exprès des autres Parties.

ARTICLE 24 - LOI APPLICABLE ET JURIDICTION

Tout litige relatif notamment à la formation, la validité, l'interprétation, l'exécution ou la rupture du présent Pacte, et plus généralement aux relations liant les Parties, sera soumis à la loi belge.

En cas de différend, controverse ou réclamation découlant du présent Pacte ou en relation avec celui-ci, les Parties conviennent de tenter, avant toute saisine d'une

juridiction judiciaire, de trouver une issue amiable à ces différend, controverse ou réclamation, en déployant tout effort raisonnable.

A ce titre, toute Partie souhaitant enclencher la procédure de règlement des différends à l'amiable devra envoyer une notification aux Parties concernées, qui devra mentionner la nature du différend et inclure tous documents s'y rapportant.

Si le différend n'a pas été réglé dans un délai de trente (30) jours, les parties conviennent de soumettre ce différend à la compétence exclusive du système légal belge.

Le présent Pacte est établi en autant d'exemplaires originaux que de Parties. Il sera remis un exemplaire à chaque Partie.

Fait à Court-Saint-Etienne, le 11 mai 2020.

Signatures de l'ensemble des Parties au présent Pacte :

Tancrède d'Aspremont



Bastien Nothomb



Harry Usuwiel



Jean Wilberz



APPENDIX

G

FINANCIAL PLAN

G.0.1 Amortization Table

					Amortization table
2021	2022	2023	2024	2025	Total
236,32 €	236,32 €	236,32 €	236,32 €	236,32 €	1 181,62 €
330,58 €	330,58 €	330,58 €	330,58 €	330,58 €	1 652,89 €
82,64 €	82,64 €	82,64 €	82,64 €	82,64 €	413,22 €
	165,29 €	165,29 €	165,29 €	165,29 €	661,16 €
			413,22 €	413,22 €	826,45 €
			165,29 €	165,29 €	330,58 €
649,55 €	814,84 €	814,84 €	1 393,35 €	1 393,35 €	5 065,92 €

Table G.1: Amortization table

APPENDIX

H

MARKETING & COMMUNICATION PLAN

H.0.1 Website Hosting on OVH

27/03/2020

Récapitulatif - OVHcloud



[Quitter](#)

Récapitulatif

✓ — ✓ — 3 — 4 — 5 — 6

Prévisualisation de votre commande

Installation

1-click module Wordpress	*001.001	0.00 €
1-click module Wordpress purchase (only applicable 1 time)	*001.001	0.00 €
Private SQL 512M	*001.003	0.00 €
perf2014x1	*001	0.00 €
Web hosting Perfx1 2014 offer Installation fees	*001	0.00 €
1000 pops, 1000 mailing list	*001.002	0.00 €
included in the plan: 1000 pops, 1000 mailing lists Installation fees	*001.002	0.00 €

Création

Demande de création d'un .io - 1 an	guinevere.io	31.69 €
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Abonnement

included in the plan: 1 private sql 512M Included sql private	*001.003	0.00 €
Web hosting Perfx1 2014 offer rental for 12 months	*001	119.88 €
included in the plan: 1000 pops, 1000 mailing lists rental for 12 months	*001.002	0.00 €

Code promo

+

Total HT 151,57 €

TVA 30,31 €

Total TTC 181,88 €

[< Retour](#)

[Continuer >](#)

https://www.ovh.com/fr/order/domain/?domain_name=guinevere.co&form_id=domain_search_form#/legacy/domain/middleOrder

1/1

Figure H.1: OVH Hosting Bill

H.0.2 Website Mockups

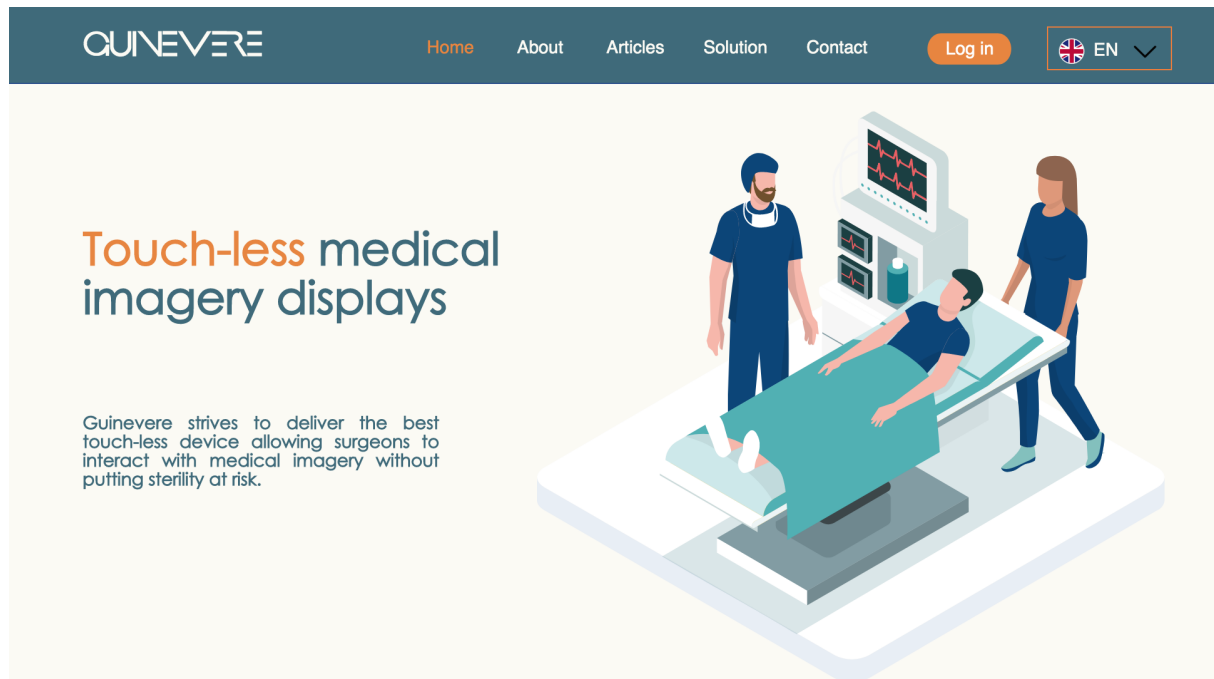


Figure H.2: Website Homepage Mockup

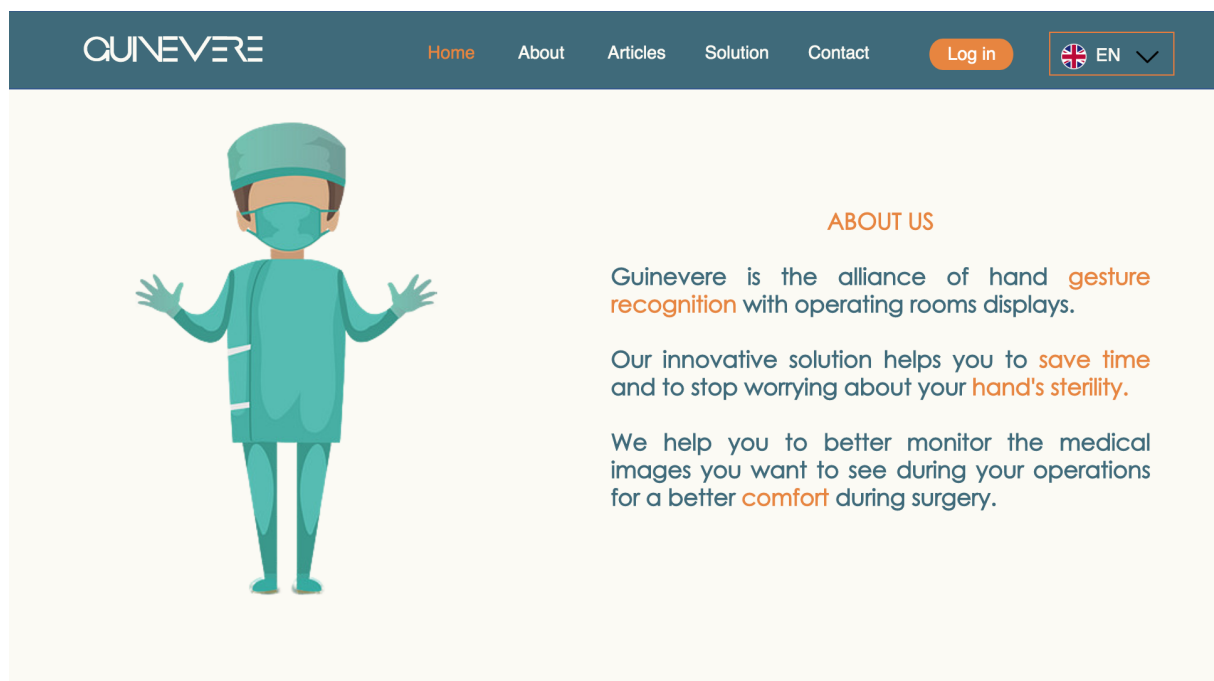


Figure H.3: Website About Page Mockup

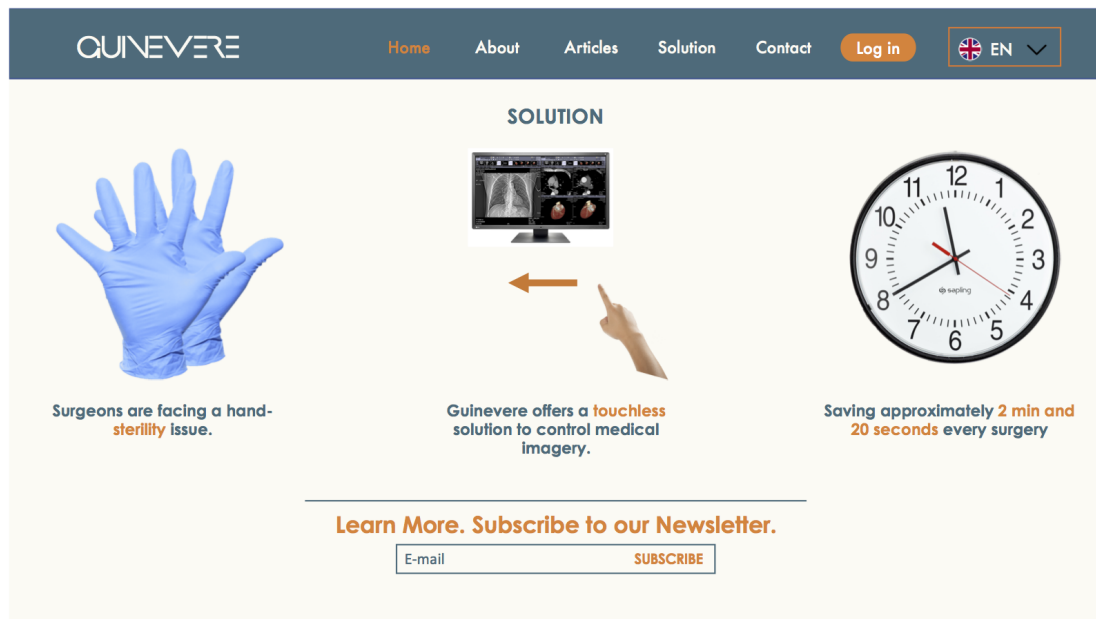


Figure H.4: Website Solution Page Mockup



Figure H.5: Website Team Page Mockup

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
CPME - Collège des Doyens

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